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ABSTRACT

With the Arab oil embargo of 1973, the United States became aware of its dependence on foreign fuel to maintain its productive capacity, employment base, political autonomy, strategic security, and living standard. An engineering Task Force on Energy was appointed to provide an informed assessment of the realistic strategies that could be initiated if the United States chose to become as independent as possible of foreign sources by 1985, based on technology now known or applicable by that date. This publication presents the analysis, findings, and conclusions of that task force. The task force concludes that the achievement of energy self-sufficiency in one decade would require enormous efforts including voluntary reduction of energy consumption and development of available fuel resources. Central to this report are the roles of government, industry, and the public in advancing a comprehensive energy program in the next decade. Specific considerations discussed in the report include supply and demand, conservation potentials, oil and gas, shale oil, coal supply, and electricity prospects, program constraints and responsibilities beyond 1985. (Author/MA)

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U.S. Energy Prospects

AN ENGINEERING VIEWPOINT

NATIONAL ACADEMY OF ENGINEERING

SE 019 999

U. S. ENERGY PROSPECTS: AN ENGINEERING VIEWPOINT

A report prepared by the
TASK FORCE ON ENERGY
of the
NATIONAL ACADEMY OF ENGINEERING

National Academy of Engineering Washington, D. C. 1974

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FOREWORD

As a result of the October 1973 oil embargo and subsequent large increases in the cost of imported oil, the National Academy of Engineering established a Task Force on Energy to prepare an assessment of realistic steps that might be taken to increase domestic energy supplies and decrease consumption during the next 10 years (defined as before 1985). This is the resulting report by the Task Force.

The names and affiliations of the members of the Task Force on Energy are given in Appendix A. The members of the Task Force and I both believe it is important to make it clear that many of the members of the Task Force, as well as some of those assisting with the work, have had long associations with industrial companies involved in energy supply and distribution. A number have also had significant government responsibilities in the past, but no present government employees were involved in the activities of the Task Force.

The Task Force sought to assess the practical engineering feasibility and probable output of major production programs in specific energy areas. It also studied improvements in efficiency and methods of reducing demand that, if initiated now--that is, in 1974--and carried out successfully, could lead to significantly reduced requirements for energy imports before the end of 1985. The Task Force reviewed each of the potential programs to identify the major actions that would be needed by government and industry to initiate and implement them, if desired, and also assessed their physical, technical, cost (money, resources, and environment), and schedule aspects.

Because of the short time available for this study and the large and growing number of analytical studies by others, the Task Force did not carry out new research, but, instead, sought to apply its judgment and experience to arrive at the results contained in this report, which must be considered in this light.

Based on the information available and on its own judgment, the Task Force undertook to do four things. First, it sought to assess the magnitude of potential domestic energy supplies and demands between now and 1985. Then it sought to determine what might realistically be done to increase supply and reduce demand in each of the energy areas considered in terms of the requirements for government and industry actions, the costs in dollars, manpower, water, and materials, and the effect on the environment. Then the Task Force sought to estimate the collective results, costs, and resource requirements of the programs from an overall point of view. Lastly, the Task Force sought to suggest key factors involved in implementation of some or all of the programs studied.

The Task Force has not attempted to pass judgment on the overall desirability of the various programs, including their social and economic consequences. Nor has the Task Force attempted to pass judgment on whether domestic energy self-sufficiency is a wise policy or when it might actually be accomplished, if decided to be in the national interest. The programs considered by the Task Force, if all done concurrently and if fully successful, would substantially reduce the need for imports by the mid-1980's; but the costs would be high and there are many contingencies to be considered.

The Task Force sought to determine what might realistically be done in each of the energy areas with the present government-industrial framework under conditions of considerable incentive and urgency but without direct government direction and intervention characteristic of a "wartime" effort.

Obviously, this study is only a beginning, and much more needs to be done to examine many of the questions and problems involved in greater depth. However, it is hoped that this report will provide guidance for such additional work as well as serving as a basis for broad policy considerations and decisions.

The work on this report received encouragement and cooperation from many quarters. In particular, the support of Mr. William E. Simon, then Director, Federal Energy Office, was a key factor in the decision to proceed.

I would like to thank those Academy members and others who gave so generously of their time and energies in the preparation and review of this report In particular, both the Task Force and I would like to express special appreciation for the contributions made by Mr. Eric H. Reichl of the Consolidation Coal Company and Mr. John E. Robb of Bechtel Incorporated. It has been the unselfish contributions of all concerned that provide the National Academy of Engineering with the breadth and depth to make responsible comments on considerations of such national importance.

Robert C. Seamans, Jr.
President
National Academy of Engineering

May 16, 1974

NATIONAL ACADEMY OF ENGINEERING

The National Academy of Engineering was established in December 1964. The Academy is independent and autonomous in its organization and election of members, and shares in the responsibility given the National Academy of Sciences under the 1863 congressional act of incorporation to advise the United States government, upon request, in all areas of science and engineering.

The National Academy of Engineering, aware of its responsibilities to the government, the engineering community, and the nation:

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6. Recognizes in an appropriate manner outstanding contributions to the nation by leading engineers.

The study was supported by funds provided by the National Academy of Sciences and National Academy of Engineering.

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SUMMARY

Suddenly and dramatically, in October 1973, when the Arab oil embargo was imposed, the United States became aware of its dependence on foreign fuel to maintain its productive capacity, employment base, political autonomy, strategic security, and living standard. During the subsequent five months of the oil shortage, the complex of problems, issues, resources, and habits connected with the Nation's energy supply, distribution, and use was a fundamental concern of the government, the industry, and, indeed, the whole American society. In this context, the National Academy of Engineering appointed a Task Force on Energy to provide an informed, reasoned, and prompt assessment of the technological range of actions that would have to be taken if the United States chose to become as independent as possible of foreign sources of energy in, say, a decade — that is, by 1985.

This report presents the analysis, findings, and conclusions of the Task Force. The Task Force concludes that, by any standard, the achievement of energy self-sufficiency in one decade would require enormous efforts but assumes the undesirability of a wartime "crash" program with its implications of government direction and intervention. Basically, it would be necessary to reduce the consumption of energy voluntarily, by means of increased efficiencies and reduced wastefulness, and to develop the fuel resources available in the United States with the best technology now available. Simultaneously, a major program would need to be pursued in research and development on advanced techniques in energy production and conservation for the future.

Central to this report are the roles of government, industry, and the public in advancing a comprehensive energy program in the next decade. The Task Force recognizes that achieving this goal would require a series of intermingled political and social decisions by the American community. The fundamental decisions toward that end should be made this year.

Supply and Demand: On the basis of recent historical trends the demand for energy in the United States could surge to the equivalent of 58 million barrels of oil per day (MBPD) by 1985--more than 55 percent greater than 1973 consumption of 37.2 MBPD. However, if major initiatives are undertaken to conserve the use of energy, the demand by 1985 could possibly be reduced to some 49 to 50 MBPD, which would still require a significant increase in energy supply during the next decade.

In 1973, domestic sources supplied the equivalent of 30.6 MBPD of the energy consumed. The rest came from imports of crude oil and natural gas. Projections made by industry experts in 1972 and in the pre-embargo months of 1973 indicated that domestic supplies could rise to about 40 MBPD by 1985 based on the then projected large-scale program. This study finds that if appropriate and timely actions are taken, domestic production could be further increased to about 49 MBPD in 1985. If this happens, the Nation's energy demand in 1985 could be satisfied by domestic energy supply sources, so long as significant conservation measures are taken by all consumers.

The gap between the domestic supply capabilities and the demand, even with extensive conservation, cannot be closed quickly. Oil imports will probably have to rise to a level of 8 to 9 MBPD by 1977 or 1978 in order to meet the overall demand by this period. Thereafter, as new domestic sources become productive, the need for oil imports could diminish.

It may not be possible or even desirable to cease importation altogether, even by 1985. This study forecasts that maximum probable domestic production of liquid hydrocarbons from all sources could be about 13.6 MBPD by 1985--still far short of the 1973 consumption of 16.2 MBPD. Therefore, unless major oil conservation practices are implemented, including converting some present uses of oil to more readily available forms of energy, oil will continue to be imported, at least until coal-based synthetic fuels can be brought into large-scale production.

Conservation Potentials: Increases in the price of energy, resulting from inexorably higher costs of development, production, supplies, labor, and capital, will provide a compelling incentive for the voluntary conservation of energy and will help promote the replacement of inefficient machines and methods with more efficient ones. Timely and intensive public information campaigns as well as economic and social incentives could guide business, industry, government, and individual consumers to reduce their energy demands by the equivalent of 8 to 9 MBPD below the historical extrapolations for 1985, the Task Force estimates.

Areas where major savings are considered possible include: increased adoption of small cars with less power equipment, improvement in the efficiency of industrial products and processes, better insulation and more efficient heating and cooling systems in residential and commercial uses, and, eventually, expanded and more effective public transit systems.

While most energy conservation can be achieved through the normal working of economic forces, government leadership will be the key to methodical conservation through such actions as encouraging the labeling of efficiencies and "life-cycle" costs, stressing such considerations in its own purchases and programs, and considering efficiency improvements in allocating grants and financial assistance to transportation systems.

Oil and Gas Prospects: In 1973, more than 75 percent of the Nation's energy was supplied by oil and gas, of which about 23 percent was imported. With this dependence on imported energy, the oil embargo and price increases for imported oil came as a rude shock to the U. S. economic, political, and social structure.

The 1973 domestic oil and gas production of 22 MBPD cannot be maintained or increased without prodigious application of present technologies and the development of new technologies. Over the years, producing fields wane and new fields must be discovered and brought into production. Field production is ultimately limited by geologic conditions, and, even with such techniques as pumping and flooding, about two-thirds of the oil cannot be extracted economically. Some gas fields have formations of such low permeability that economic yields cannot be attained by conventional practices. What is more, environmental concerns have inhibited the production of oil from offshore sites.

If oil and gas prices, regulated only by a free market, reach levels at or below the expected world prices, the Task Force believes that sufficient capital can be attracted to increase production of these fuels from domestic sources, including Alaska and the Outer Continental Shelf, to as much as 27 MBPD by 1985. To achieve this, about $180 billion* would be needed.

In addition to exploration and development of new fields, major flows of oil and gas would be expected from increasing production in existing fields that are now considered marginally economic. By advancing and applying secondary and tertiary recovery techniques and developing fracturing methods to free gas in low-permeability fields, significant increments could be made, though the output would be less than from primary extraction.

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*All capital requirements are in '73-'74 dollars, and only reflect direct costs for facilities in place during this 1974-1985 period; associated infrastructure and financing costs are not included.

Shale Oil Prospects: Shale deposits are now estimated to contain some 1,800 billion barrels of oil. However, only about 6 percent of the shale is accessible in thick enough strata and with high enough oil content (30 gals per ton) to be of commercial interest today. There also are difficulties associated with the extraction of oil from the shale. If above-ground retorting methods are used, large amounts of rock would be mined treated, and discarded as tailings. Techniques to reclaim tailing areas in ways that are environmentally sound are presently unknown or uncertain. Another serious complication is that deposits are located in arid and semi-arid areas and sizeable quantities of water are required for the processing and reclamation.

The Task Force believes that these limitations will keep the rate of production of shale oil relatively low until 1985 and perhaps for longer. It estimates that shale oil production by 1985 will not exceed 0.5 MBPD despite an investment of between $3 billion and $5 billion. To achieve even this production will require that larger tracts be provided for leasing than are presently permitted, that environmentally acceptable methods for disposing of tailings be determined, possibly with government assistance, and that sufficient water be available.

Coal Supply Prospects: Recoverable coal reserves in the United States are capable of supplying many energy needs for centuries. This study concludes that the 1973 coal production rate of 600 million tons per year (MTPY) could be doubled to at least 1,260 MTPY by 1985. Of this, about 700 MTPY could be consumed in direct firing for generating electricity, 310 MTPY could be used for producing synthetic gas and oil and the balance for industrial uses and export. About $21 billion of additional capital investment would be required by 1985 to maintain eastern surface mining at about 1973 levels, to increase eastern underground output to what its capacity was in 1940, and to expand western surface mining to an annual rate of 560 MTPY.

These production goals would require that federal coal-bearing lands in the West be made available for immediate leasing, that interim and longer-term mine operating regulations be reviewed and accepted, that environmental requirements for reclamation and for burning coal be determined and clarified. All this would help create a stable and lasting producer-user relationship. Coal, competing against other fuel sources, would also have to reach a price level that would attract the investment capital needed for more production.

There are serious barriers to increased coal production, principally transport. More unit-trains, new slurry and gas pipelines, and enlarged capacities for the Nation's inland waterway systems would be needed to transport as much as 660 MTPY of additional coal.

Moreover, capital would be needed to finance the conversion of coal to synthetic fuels. The technology for transforming coal to methane, or synthetic natural gas, is ready for commercial application, the Task

Force believes. By 1985 there could be as many as 20 syngas plants producing an aggregate of 5 billion cubic feet per day, the energy equivalent of 0.8 MBPD of oil. The production of methanol is technologically similar to methane production, and the production potential is largely dependent on the development of a market and on the pricing of competitive liquid fuels. Under the circumstances, the Task Force estimates that production of an equivalent of 0.3 MBPD is likely by 1985. The market potential for medium-Btu gas, principally for power generation, will also determine the desired production level; about 0.3 MBPD is foreseen for 1985.

Liquefaction of coal into a synthetic crude oil, or syncrude, is potentially the most important technology to be exploited. However, the present processes are costly and would lead to syncrude prices well above the likely world price levels of oil in the future. To develop commercially useful alternate processes, an aggressive R&D program would be imperative. The costs and risks associated with such developments would probably require substantial government funding in addition to private capital. Although the lead time needed to develop and deploy production plants make it unlikely that syncrude production will exceed about 0.3 MBPD by 1985, the Task Force believes that the longer term importance of liquefaction as a major source of liquid fuels suggests that an early demonstration of economical processes be given a high national priority.

The aggregate capital requirements for the production of synthetic fuels from coal at the projected 1985 levels will vary, depending on the presently uncertain development costs to achieve commercial-scale operations. A range from $16 billion to $22 billion is considered likely. This sum would be in addition to the $21 billion of estimated capital needed to extract and transport coal for all purposes.

Electricity Prospects: Electrical power generation has been increasing at about 7 percent per year recently, about double the overall rate of increase in energy consumption. From an energy standpoint, a continuation of this trend to electrification is desirable because of the wide range of fuels that can be used. In 1973 coal generated 44 percent of the electricity, oil and gas about 37 percent, and hydropower accounted for most of the remainder. With only 25 stations on-line at the start of 1974, nuclear powered electricity has been a small part of the Nation's present energy supply.

The total 1973 generating capacity was 435 Gigawatts electric (Gwe)--a Gigawatt equals 1 million Kilowatts. By 1985 this capacity could be more than doubled to about 980 Gwe. The implication for the Nation's total fuel mix is significant: coal and nuclear energy could reduce the need for oil and gas. The Task Force estimates that coal-fired electricity plants could account for 220 Gwe of the increased capacity and nuclear fission plants for an additional 300 Gwe. These increases, together with a modest increase in the use of hydropower and geothermal generating stations, would provide the estimated growth in electrical capacity. Although the capacity of oil- and gas-fired plants would remain about constant, it is anticipated that they would be utilized principally for intermittent cycling and peaking generation, and thus their fuel consumption would actually decline.

The expansion of generating capacity to the projected level, together with concurrent expansion of transmission and distribution networks, would involve high costs. Capital investment of more than $300 billion is likely to be needed. It would not be possible to raise this capital and achieve this expansion, the Task Force observes, without several important actions. The expansion of coal-fired plants, or the reconversion of oil or gas plants back to coal, for example, will depend largely upon the resolution of sulfur dioxide (SO_2) emission standards. The Task Force believes that although reliable and effective SO_2 scrubbers do not now exist, these can be developed in a few years. In the interim period, environmental regulations could be put in effect to permit the controlled, intermittent operation of coal-fired generating stations during the overhaul of malfunctioning scrubbers. As it is now, regulations require the whole plant to shut down when scrubbers are not working properly. Alternatively, in some locations, consideration could be given to use of high stacks for SO_2 dispersion and to switching to alternate low-sulfur fuels during unfavorable meteorological conditions.

An increase in the size and number of previously projected nuclear power plants would seem to be possible, the Task Force states, if the administrative procedures that have lengthened their lead times from drawingboard to on-line output to 9 to 10 years could be reduced to 6 to 7 years, which was the time-frame only 5 years ago. Such actions as consolidating public hearings, approving generic designs for duplicate construction, pre-selecting and approving new sites, and reducing retrofitting during construction would reduce the lead time. The Task Force is confident that the present state of the art in nuclear plant technology warrants such changes without reducing safety.

Other decisions would also be needed to provide direction and stability for the efforts needed to acquire and enrich uranium fuels in order to expand the Nation's nuclear generating capacity. In addition to opening federal lands for mining, the government would have to resolve uranium import policies and encourage electrical utilities to enter into long-term contracts for uranium supplies. Removing or reducing the classification of enrichment information, resolving the plutonium recycling dilemma, and restructuring the government/commercial interfaces on enriching plants are some of the principal actions that would be needed soon to ensure sufficient nuclear fuel capacity. Capital requirements for nuclear mining and enrichment could range from $11 billion to $14 billion.

Program Constraints: The Task Force recognizes factors that could seriously restrict any major program of the dimensions that would be required to approach energy self-sufficiency.

o Capital: Private capital requirements for production facilities are estimated at $500 billion to $600 billion. This sum does not include working capital, dividends, debt service, and other financial obligations. Nor are government R&D and production facilities (e.g., uranium enrichment operations) included in this estimate.

o Water: A serious concern for producing oil from shale or synthetic fuels from coal in the quantities considered possible by 1985 is the availability of water. It is also essential for rehabilitating land after surface mining and for cooling electrical power plants. In the West particularly, the limited availability of water as well as the issue of riparian rights would have to be examined carefully on a case-by-case basis.

o Environment: While energy is essential to the quality of life, its production disrupts the environment in many ways. Methods need to be found to reconcile energy with the environment. Land reclamation after coal and shale mining; protective measures associated with oil extraction; and effective techniques for sulfur removal either at the coal mine or the power plant are only a few problems that require solutions. The Task Force recognizes the importance of protecting the natural environment and safeguarding human health and believes that these concerns can be dealt with by appropriate technology and realistic standards.

o Manpower: An estimated 1.4 million people are engaged in energy-related activities today. To run the programs presented in this report would require several hundred thousand more. Substantial increases would be needed in engineering, in construction trades, and in mining, transportation, and technical and managerial work. The Task Force notes with considerable anxiety the drop in student enrollment in engineering curricula during the past four years. It will be important to reverse this trend as soon as possible. In addition, engineering manpower shortages may be alleviated in part by transferring engineers from fields outside the energy industry, by special training programs, and by careful organization of engineering assignments.

Program Responsibilities: Federal departments and agencies now deal with energy policies and programs in a variety of disparate ways. Although the Federal Energy Administration recently has been established, the Administration and the Congress are still considering creation of a special energy R&D agency and/or a department of energy and natural resources. In its engineering view of the energy problem, the Task Force did not address organizational questions, although it recognized that the government would have to assume responsibility for the following:

- o Collection, development, evaluation, and publication of projections for energy demands and supplies;
- o Development of national energy policies for consideration by the Executive Department and the Congress, and coordination of policy development with other federal, state, and

local government agencies as well as in the energy industries;

- Preparation of strategies for assuring adequate energy supplies at reasonable costs and minimum impact on the environment;
- Development and implementation of programs for conserving energy and measures for increasing efficiencies in energy utilization;
- Collection and publication of data on resource requirements and availability for such critical areas as engineering, scientific, and construction manpower, equipment and manufacturing capabilities, and basic materials availability;
- Organization of allocation and rationing programs such as manpower, equipment, and resources, as well as of energy supplies, if necessary;
- Identification and assistance in removing institutional roadblocks in the production and use of energy resources;
- Development and application of financial incentives where clearly required, including development and overall surveillance of joint government-industry partnerships in programs requiring public support;
- Examination and resolution of critical environmental problems such as water supply, land use, and air quality;
- Development and coordination of international programs in energy areas;
- Support of R&D when the risks are too great for private investors;
- Coordination of programs for long-range and basic research in energy areas;
- Provision for dissemination of information and advice to the general public and special groups.

Once a politically defined and economically practical set of national objectives and policies are established, the various segments of the energy industry should be able to accelerate and expand their efforts to provide more energy supplies in the needed forms. Industry would have many difficult tasks to carry out in a timely, cost-effective, and beneficial manner. These include, but are not limited to, the following:

- Expansion of energy facilities requires very large amounts of money from internal funds, equity funding (stock), and bonds or loans; such funds can be obtained if the industries have stable and adequate revenue to cover their costs, repay the loans or bonds, and provide the stockholders with an adequate return.

- Rapid and detailed planning would be carried out in response to new objectives and goals as well as within any new energy supply-demand situation.
- Once detailed plans are evolved and critical problems identified, the various organizations--along with their managers and key personnel--have to be reorganized and redirected as necessary to undertake the various tasks on an urgent basis. Whether these are new exploration programs, new mines, new oil refineries, construction of facilities, operation of new mines or plants, manufacturing of new equipment, or provision of development support, the industrial structure will be the same, but substantial changes would surely evolve and experienced planners and managers would most likely be at a premium.
- There will surely be a critical shortage of many types of manpower, particularly engineers and skilled construction workers; major programs will be needed to make more efficient and effective use of available manpower, to utilize less skilled manpower where practicable, and to train more personnel as rapidly as possible.
- Full consideration would have to be given to possible environmental effects and to reasonable cost/benefit decisions for industrial programs posing problems to the environment; close cooperation with government should allow quicker decisions if industry does an adequate job of considering the issues. Similar consideration would be due in safety and health as well.
- Many energy programs would require substantial support in terms of development, and effort would need to be diverted from other research and development activities to provide such support.
- Industry would have to establish and maintain credibility with the public as well as with the government for understanding and cooperation to be real and effective.

Beyond 1985: Achieving the complete range of programs described in this report by 1985 is not considered by the Task Force to be of high probability. Even if it is accomplished, the United States would be buying time. For beyond 1985 looms an ominous prospect of even greater demands for energy from ever-increasing and ever-rising expectations at home and abroad. Unless innovative ways are developed for conserving and using energy and substantial new sources and new technologies are found for increasing energy supplies, the strategies presented by the Task Force would only postpone a grim future of energy scarcity.

This report shows what can be done with today's technology. If the United States is to have options beyond 1985, a well-planned, wide-ranging program of research and development is essential.

Chapter 1

INTRODUCTION

PURPOSE AND SCOPE

The United States, with its large resources of coal, oil, gas, uranium, and water power, has been largely self-sufficient with respect to its energy supplies until recently. Although the country became a net importer of energy about 1950, the quantities were small until about 1958. Since then, energy imports, mainly oil, have grown at rates of 7 to 10 percent per year. By comparison, during the same period energy consumption has grown more than 4 1/4 percent per year and domestic energy production at about 3 3/4 percent per year. During the past few years, however, domestic energy production has grown at a slower rate, less than 1 percent per year, as gas and oil have reached peak production rates; and a variety of factors have limited the use of coal.

The recent embargo on oil imports into the United States from some Middle East and North African production areas and the large, sudden increase in essentially all imported oil prices have raised serious and urgent questions of national energy policy. These include the feasibility and desirability of reducing or eliminating oil imports--becoming self-sufficient in energy--along with questions as to the means of accomplishing such objectives, the time required, and the costs--in money, resources, social and economic changes, effects on the environment, etc.

This report addresses essential questions related to the reduction or elimination of energy imports, but it does not seek to answer all of the questions outlined above or those that are necessary to determine national energy policy. The report seeks to provide an appraisal on a practical engineering and judgmental basis on the following matters:

- The magnitude of domestic energy supplies and demands between now and 1985 in the United States.
- Realistic possible programs and estimated production achievements in each of the significant energy areas, along with the implementing actions that would be required by government and industry, the schedules, costs, risks, resource requirements (men, money, materials, water, etc.), and other constraints.
- An assessment of the potential total production (or decreased demand) if all programs identified were carried out simultaneously, along with an evaluation of the possibilities and costs of such an overall program in terms of available resources and other constraints.
- Important factors to be considered in the implementation of those portions of the program identified that might be considered desirable as a matter of national policy.

Since in the judgment of the Task Force the next decade is the most critical period for reducing or eliminating imports, the study was confined to the time period between the present and 1985. During this period, research and development would be unlikely to produce new sources of energy on a large scale, and time factors would limit increases of supply to expanding domestic production from known sources.

A further basic consideration was that, while it was assumed that production programs, if carried out, would be implemented aggressively both by government and industry with a real sense of urgency and high priority on resources, it was also assumed that they would be done without the type of government structure, directives, and direct financial support characteristic of a wartime economy.

A further objective was to identify to the extent possible those specific actions that should be taken now, in 1974, if it is desired to initiate or expand the various energy programs that could have significant impact before 1985.

No attempt is made to pass judgment on whether energy self-sufficiency is a wise policy, desirable, or even feasible. This report does not consider questions of social inequities or changes, economic dislocations, etc., that may arise from costs of energy programs or failures to achieve specific energy production goals. It does not consider the issues of acceptable changes in living standards, life styles, or what can be accepted in terms of changes in the environment. These are important questions that must be considered, along with others related to national security, the international monetary system, etc., in arriving at a national energy policy.

This report does not deal with long-range R&D efforts that can have a significant effect only beyond the next 10 to 15 years. Such efforts, however, will be essential to the longer-term satisfaction of U.S. energy requirements.

APPROACH

Many excellent studies on national energy have provided background data for this analysis. These reference studies are listed in Appendix D, and their forecasts are summarized in Appendix C. Few of these address the real-life constraints now experienced by industry and government in attempting any energy expansion project.

UNITS

The reader is cautioned that energy units and conversion factors among the reference documents vary widely. The units and conversion factors used in this report will be found in Appendix B.

Abbreviations used in this report differ from those in some of the energy industry. For simplicity, a set of terms was adopted with the non-technical reader in mind.

ABBREVIATIONS USED

Abbreviation	Term
Kwe	Kilowatts electrical
Mwe	Megawatts electrical, or thousands of Kwe
Gwe	Gigawatts electrical, or thousands of Mwe
Kwh	Kilowatt hours
MBPD	Millions of barrels of oil equivalent per day
MTPY	Millions of tons per year (of solids, e.g., coal)
BCFD	Billions of cubic feet per day (of gas)
TCFY	Trillions of cubic feet per year (of gas)

It should also be noted that in this report "demand" is defined as being the sum of domestic consumption plus exports plus any change in inventory (usually small or assumed to be zero) and is thus equal to domestic production plus imports. The use of these terms varies widely in the energy industry and in the literature.

Unless otherwise noted, all references to costs are in terms of constant 1973-1974 dollars; inflation effects are not explicitly treated in this study.

LOGIC

Chapter 2 describes the overall dimensions of energy supply and demand in an attempt to define the significance and magnitude of the problem over the next decade.

The next five chapters of this report divide the demand and supply into individual topics and discuss present status as well as the changes that are possible in the next 10 to 12 years. Potentially beneficial government actions that could be taken in each area are outlined, as well as schedule, cost, resource requirements, and others.

In Chapter 8 judgments on possible production levels are totaled, and examination is made of secondary constraints, such as

- Time and Schedules
- Costs and Financing
- Environment
- Water
- Manufacturing
- Manpower
- Technology

In Chapter 9 institutional arrangements are discussed, and Chapter 10 presents the conclusions.

CRITERIA

The Task Force decided that only programs and technologies that could make significant energy contributions before 1985 would be included in this analysis. Technologies and programs were included only if they met the following criteria:

- A new synthetic fuel process or other energy source must appear capable of achieving at least 0.3 MBPD production by 1985.
- Processes must be already developed or far enough developed to provide the basis of production by 1985.
- The technology or process must not rely on speculative, as opposed to reasonably assured, R&D success.
- Development of the technology or process must not involve an unreasonable financial risk to private enterprise.
- The technology must be within the limits of available resources in manpower, facilities, water, and capital.

These criteria exclude the following technologies:

- Solar Electric Power
- Fusion Power
- Fast Breeders
- Tidal Power
- Wind Power
- Hydrogen Fuels
- Nonindustrial Electrical Automobiles
- Power from Ocean Temperature Differences

Although not treated in this analysis, the Task Force believes that several of these are important for the long term and that appropriate R&D efforts should proceed vigorously on them now.

Chapter 2

THE PROBLEM

BACKGROUND

Increasing demand for energy and decreasing or constant domestic production of oil and gas have led the United States to import increasing amounts of oil. Up until three years ago, these imports were largely from Canada and South America.

In 1970 U.S. energy demand was equivalent to 33.2 million barrels* per day (MBPD) of oil.[1] Energy production from domestic sources was equivalent to 29.3 MBPD. Since 1970 the domestic supplies have only increased to 30.6 MBPD; but, by 1973, energy demands rose to 37.2 MBPD.[2] The additional supplies came almost totally from oil imported from the Middle East and North Africa.

Energy consumption has been growing in other countries also. This has led to increasing worldwide competition for energy supplies, particularly environmentally attractive ones such as low-sulfur oil and liquefied natural gas. Japan is largely dependent on imported oil, coal, and gas. The United Kingdom and Europe import more than half of their energy requirements, largely from the Middle East and Africa. Although world energy productive capacity has been increasing, demand has grown at a higher rate and spare capacity has become quite small. One result of these pressures is that worldwide prices of oil have increased substantially during the past years, even before the oil embargo of 1973 and the subsequent price increase.

Increased oil prices and increased dependency upon imports raise issues of reliability of supply and balance of trade. They also strain the international monetary system.

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*Assumed at 5.8 million Btu per barrel.

Another problem is a growing dependence on foreign refineries. Crude oil imports were for years limited to 10 percent of domestic production, but residual oil imports were not limited. In this circumstance, new "topping" refineries were built outside the United States to produce large amounts of residual oil, which could be imported freely. More recently, relaxation of import controls has spurred construction of domestic refineries; but it will take time before these are in operation. Also, if domestic crude production can be increased, additional domestic refineries will be needed, posing environmental siting problems.

Another concern is that the production rates in the major oil-supplying countries may not keep up with projected global requirements for oil. Production capacity in 1973 was barely adequate to meet worldwide demands. Exporting countries having large oil reserves may not wish to expand their facilities since their income from oil already exceeds their domestic needs. They may well wish to extend their oil production over a longer period of time.

RECENT EVENTS

The recent embargo on oil imports and the oil price increases have forced attention on U. S. energy dependence.

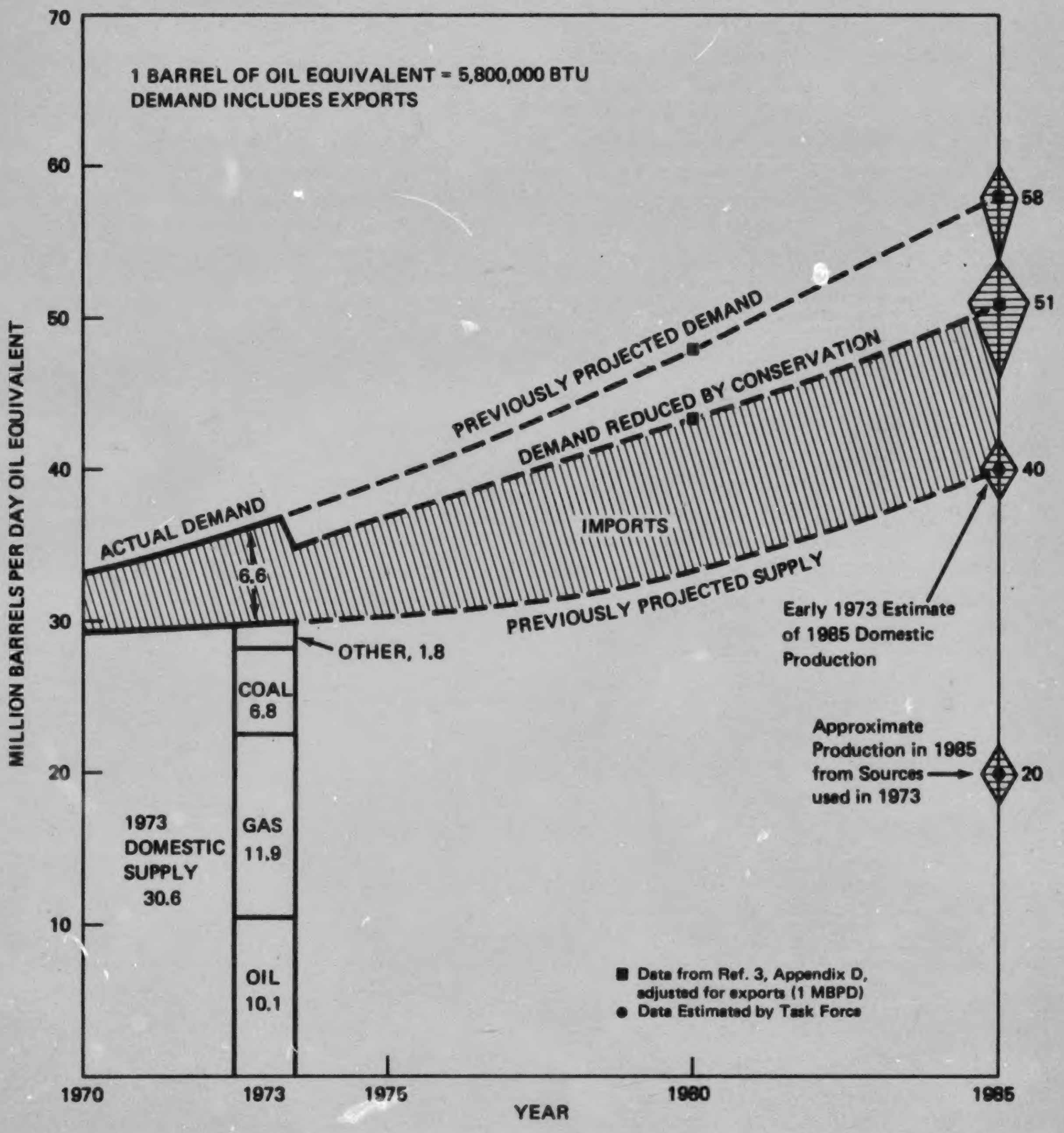
Shortfalls in energy supply resulting from the oil embargo have caused inconvenience and spot shortages. An extended or resumed embargo might lead to more serious economic consequences. World market oil prices seem likely to remain high, and long-term economic ramifications seem inevitable, including modifications in world trade and alliances.

An obvious response to this situation is to increase emphasis on reducing domestic energy demands and increasing domestic energy supplies. This response is apparent in nearly every major oil-consuming country today. For the United States, the question is: How much and by when?

HISTORICAL SUPPLY-DEMAND TRENDS

Many forecasts of this Nation's energy supply and demand trends have been made for the remainder of this century. A number of these are summarized in Appendix C. A review of these projections, which were based on historical trends predicated on the continuation of low-cost energy availability, suggests demand rates of 45 to 50 MBPD in 1980 and 54 to 60 MBPD in 1985 as probable ranges of domestic demand. The Task Force studied these demand projections and, from them, synthesized what might be regarded as a most probable forecast for general scoping purposes. This is set forth as the "Previously Projected Demand" curve in Figure 1.

FIGURE 1 U.S. ENERGY SUPPLY AND DEMAND



Several estimates have been made of the reduction in demand due to higher energy prices and emergence of an energy conservation "ethic." For purposes of analysis, the Task Force used a median deviation from the historical demand curve based on these other studies. (See, for example, the projections taken from The Nation's Energy Future, the report sent to President Nixon by Dixy Lee Ray, chairman of the Atomic Energy Commission.)

The energy supply from domestic sources is illustrated by the bar graph at the left side of Figure 1. It shows that domestic energy production for 1973 was approximately as follows:

1973 DOMESTIC ENERGY SUPPLY[2]

Source	MBPD
Crude oil and natural gas liquids	10.1
Natural gas	11.9
Coal and lignite	6.8
Hydroelectric	1.4
Nuclear	0.4
Total	30.6

Various estimates have been made of domestic supply under economic conditions predicted up until mid-1973 (Appendix C). A rough median of these is, as shown on Figure 1, about 40 MBPD in 1985, an increase of about 10 MBPD over 1973 domestic production levels.

FUTURE OUTLOOK

The Task Force concluded that the future supplies and demands could most easily be understood if energy were assessed relative to supply and demand in 1973.

Domestic energy supply was 30.6 MBPD in 1973. These domestic sources of energy, if not expanded or supplemented with additional sources, would produce, in the judgment of the Task Force, only about 20 MBPD in 1985. Thus, the programs envisaged by industry in early 1973 or before to achieve about 40 MBPD by 1985 contemplated a total increase on the order of 20 MBPD in the intervening period — a large and costly effort.

Under these circumstances, it was contemplated prior to the oil embargo that the difference between demand and supply, about 18 MBPD, would be made up by imports. The risks, as well as the costs ($30 billion per year or more by 1985 at $5 per barrel), were already a matter of serious concern.

Assuming major initiatives to reduce demand by 1985 to a net of 51 MBPD, the net increase in supply from present domestic production levels to approach zero imports would need to be about 20 MBPD. The "new" production would have to yield about 30 MBPD, which equals the entire domestic energy output in 1973. Needless to say, increasing the domestic production by such a factor (and decreasing consumption by 7 MBPD as well) in order to achieve zero imports would be a monumental endeavor, whether done by 1985 or later.

While these figures are imprecise, they indicate the magnitude of the energy problem. They also indicate the scope of the programs required to provide adequate, reliable, and reasonably economic domestic sources of energy for the United States in the years just ahead. In 10 years domestic supplies must double.

The supply-demand picture can be considered to be made up of the following components:

- Reductions in consumption through improved efficiency and conservation practices.
- Base production from existing domestic sources — declining in the case of oil, gas, and coal.
- Enhanced production from existing domestic sources.
- Production from new or undeveloped domestic sources.
- Imports from foreign sources.
- Actual shortfalls, resulting in rationing or allocation to forcibly reduce consumption to available supply.

These divisions are arbitrary but useful in the context of the present analysis. If we are to avoid shortages but still wish to reduce imports quickly, emphasis must be placed principally on enhanced production (e.g., secondary and tertiary oil recovery) and consumer-use reduction. New sources of energy will become available only in later years.

Some further implications can be drawn. If imports are restored soon to the mid-1973 level, the supply would seem to be marginally adequate for several years as long as projected decreases in demand can be implemented. However, shortages will appear soon thereafter if imports are not expanded or domestic supplies increased in the intervening time. It will be several years before domestic production will increase to the rate at which demand, as modified by conservation, is expected to increase. Therefore, it would appear that significant oil importation levels will indeed be necessary in the short term, even if a major effort toward increased self-sufficiency is launched now. If adequate imports are not available, the economic consequences of prolonged shortages will be serious.

Considerable effort must be extended toward early significant demand reduction through both technology improvements and conservation practices. To the extent that this effort cannot reduce demand and to the extent that the Nation does not wish to rely upon imported energy, our domestic supplies must be increased.

These possibilities are discussed in the next few chapters.

Chapter 3

CONSERVATION POTENTIAL

INTRODUCTION AND OVERVIEW

The Task Force considered two categories of conservation measures that could reduce the energy projections for 1985.

The first category and earliest means for reducing energy demand has been referred to as the "conservation ethic" — avoiding waste and "doing with less." It includes voluntary conservation of fuel usage and governmental fuel allocations that have been the mechanisms employed during the imposition of the oil embargo.

Price increases are also expected to stimulate voluntary conservation. A number of estimates of demand elasticity with price have been made by others based on economic theory. Differences exist in the elasticity projected in these estimates and in the social and political consequences of sudden price increases. But they concur that adjustment in price, the traditional method of equating demand and supply, will prove effective in energy conservation over the long run,

In the past, energy surplus and low prices created a tendency to be wasteful. In such a climate, consumption was effectively encouraged by promotional efforts of primary energy producers and by the offerings of manufacturers of energy-consuming devices. The increased prices already realized for energy and the prospects of further rise in the next decade should be effective in reducing these causes for unnecessary energy consumption.

In this analysis, conservation potentials were not based on demand elasticity projections. Rather, they reflect estimates of the changes in demand and use that are technologically and economically achievable before about 1985.

The second category for conserving energy involves some added capital investment and/or employment of new technology on the part of users. Such measures can be stimulated by higher energy prices or by expected limitations to availability and continuity of desired energy forms.

The cost of energy over the useful life of a device has often been ignored by builders, contractors, and owners in favor of convenience and low initial cost. Future choices of energy supply and energy-consuming equipment will undoubtedly consider life-cycle energy costs, but the Task Force recognizes that this involves rather substantial institutional changes and in itself will probably be slow to evolve.

New construction of industrial, commercial, residential, and transportation facilities can, of course, be the immediate beneficiaries of more efficient energy-conserving technology and investment. But the pace of new construction usually averages 3 percent to 6 percent per year of the existing facility base. At this pace, even a decade of expansion will make limited reduction on the energy demands projected for these purposes.

A larger opportunity is represented by conversion of existing facilities to lower-cost or more energy-efficient forms. Such retrofitting may become attractive in some areas where availability of energy may be jeopardized or where prices are significantly higher than alternate fuels. But the Task Force concluded that retrofitting of existing facilities would proceed at even a slower pace than conversion of new facilities to more efficient energy forms, although it would be spurred by progress in the latter.

Accordingly, the effects from this second category will be slow in coming, but once implemented they will be continuing. The effects from the "doing with less" category are immediate, but they may not persist with time because of the individual constraints required to make them succeed.

At this point, the Task Force has little data on which to base conservation trends. Having the two conservation categories in mind, its estimates were derived by examining the technological and economic demand reductions believed achievable in the areas of supply and usage.

In this connection, it was noted that a third form of conservation should be emphasized. It is the reduction of oil and gas usage through substitution of more abundant indigenous resources like coal or nuclear fuel. While such substitution for oil and gas resources does not reduce demand, it does serve the objective of energy self-sufficiency. Many examples in the second conservation category will serve this objective as well.

The above categories of energy conservation portend a complex variety of physical changes that will probably occur in each consumption sector and use area and that will reduce demand for 1985 below the levels projected earlier. This physical response of the market is the subject of this chapter.

PRESENT ENERGY SUPPLY AND DEMAND

As a basis for evaluating the potentials for the above categories of energy conservation, the Task Force examined present patterns of energy supply and demand by use area and by consumption sector.

The approximate 1973 consumption of energy, according to the major areas of use, was:

ESTIMATED 1973 U.S. ENERGY-USE PATTERN[a]

Use Area	Percentage of National Use	Equivalent MBPD
Transportation	25	8.82
Space heating	18	6.39
Process steam	16	5.75
Direct heat	11	3.87
Electric drive	8	2.73
Lighting	5	1.97
Water heating	4	1.44
Feedstocks	4	1.29
Air conditioning	3	1.09
Refrigeration	2	0.69
Cooking	1	0.35
Electrolytic processes	1	0.45
Other	2	0.84
Total	100	35.68

[a] Developed by extrapolating 1960-1968 relative trend data by use area[4] and applying to total estimated energy consumption in 1973.[2] The difference between this energy consumption and the energy demand in Chapter 2 (37.2 MBPD) is accounted for by exports and changes in stocks.

Transportation uses more energy than any other single area. It is uniquely dependent on oil as the only fuel system presently suited to the mobility of the U.S. life style. It is the area for the greatest efficiency improvement, as will be reviewed in the next section.

Other major opportunities for reducing waste and improving energy efficiency lie in energy supply for the following:

	1973 Estimated Percent of Total Energy Use
Space heating	18
Process steam	16
Direct heat	11
Water heating	4
Lighting	5
Total Opportunity	54

These areas also include major opportunities for potential electricity substitution. Together with the present all-electric use areas, they indicate that more than 60 percent of the energy system expansion in the future could, if it were a matter of national policy and resource support, be accomplished by electrification, using coal and nuclear fuels to relieve the dependence on oil and gas.

Much publicity has been given to the limited efficiency of electric conversion from fossil fuels, creating the impression that direct use of these fuels is highly efficient. At the point of use, electric power approaches 100 percent efficiency; and overall its efficiency from fuel to useful output is in the range of 30-35 percent. The efficiencies for direct use of fossil fuels depends on the application and on how well the equipment is maintained. Good industrial process steam generators can be in the range of 65-70 percent efficiency.

Well-maintained space heating systems are in the same range. On the other hand, automobile efficiency in a typical urban operating pattern can be as low as 10 percent with steady highway efficiencies running up to twice that level. Fossil-fueled water heaters are intermediate.

Another useful way to explore potentials for energy conservation is to examine the energy consumption mix according to use sectors. This information for 1973 is illustrated in the following table:

1973 US ENERGY CONSUMPTION MIX[2]

MBPD

Sector Fuel	Residential and Commercial	Industrial	Transportation	Electric Generation	Miscellaneous Unaccounted	Total Consumption
Coal	0.17	2.10	—	4.11	—	6.38
Oil	3.32	2.86	8.47	1.62	0.12	16.39
Gas	3.78	5.11	0.38	1.85	—	11.12
Hydro	—	0.02	—	1.37	—	1.39
Nuclear	—	—	—	0.40	—	0.40
Total Primary	7.27	10.09	8.85	9.35[a]	0.12	35.68
Electric Usage	1.69	1.25	0.01	6.40[a]	—	—
Total	8.96	11.34	8.86	6.40	0.12	35.68

[a] Of the 9.35 primary energy input, [illegible]40 became generation losses and the 2.95 is distributed to the use sectors.

From this table, it is noted that oil used for transportation accounts for about one-half of the total oil consumption. About 20 percent of the total energy consumption by the residential/commercial sectors, mostly space heat as illustrated in the table on p. 26, is shared about equally by oil and gas. Of the industrial heating requirements, one-half is met by gas and one-quarter by oil. Coal supplies almost half of the energy used to generate electricity, while oil and gas supply 37 percent. While power generation, space heating, and industrial heat have the greatest potential for interfuel substitution, this is not true at present for transportation. Electrification of mass transit and specialized vehicles (such as delivery trucks and urban vehicles) should be growing rapidly by 1985, but it is not expected to enhance interfuel substitution significantly by that time.

ENERGY SAVINGS BY CONSERVATION

Experience with conservation measures in industry suggests that average energy savings of some 10 percent can be achieved without limiting output.[5] These savings are approximately two-thirds for facilities utilization and one-third for process utilization. Examples include more efficient utilization of space heating and cooling, avoiding leaks and waste, task-level lighting, and avoiding partial loading of equipment or running equipment not in use. These savings can amount to 1.5 MBPD by 1985, and energy costs now provide a stimulus for doing so.

Transportation, as mentioned in the previous section, is a major area for energy conservation, including judicious use of the automobile. Continuing the 55 mph speed limits, and even modest increases in trip reduction (travel and pooling of shopping trips) and car pooling, can save about 1 MBPD. Increases in airplane load factor, already begun, can save another 0.3 MBPD.

Finally, the residential/commercial sector provides many opportunities for conservation, depending greatly on the attitude of individual users. About 1 MBPD can be saved in home and commercial energy by the sum of actions such as raising temperatures as little as 2° in the winter, by weather stripping to avoid leaks, and by use of window shades and turning off unneeded lights and appliances. Government studies indicate that the 2° thermostat change alone would save 0.6 MBPD by 1980.[6,7] A public information program for wide dissemination of voluntary practices that will reduce demand should be very effective in this area.

ENERGY SAVING BY USE OF MORE EFFICIENT EQUIPMENT

One of the most obvious and significant reductions in consumption could be brought about by the increased use of small automobiles. Fuel consumption is almost directly proportional to car weight. Some 500 gallons of gasoline equivalent is saved in production of a 2,000-lb car compared with a 5,000-lb model; and smaller cars seem to be gaining in popularity. In the 1973-model year, for example, the industry production capacity was about 3.5 million small cars. In 1974-1975, automobile makers report that they will be able to produce about 5 million, about half of the anticipated total production. Even such sharp changes in trends, however, cannot strongly affect fuel demand from one year to the next. The average life of an automobile is about 10 years, and a change from the present mix of small cars to large cars would be relatively slow.

With the expected growth in car population, fuel demand would increase in absolute terms. Although some improvement in fuel economy (miles/gallon) can be expected from better engine design, much of this improvement would be lost with the expanded use of exhaust pollution control devices. Nevertheless, with the anticipated shift to a larger fraction of smaller cars, there could be a substantial reduction in consumption below that expected were energy supplies to remain ample. A change in our present automobile mix from the current 30:70 ratio of small to large cars to about a 50:50 ratio by 1985 would save at 1973 mileage about 1.5 MBPD. Together with opportunities for improved engines (for example, diesel stratified charge) and other energy-saving features, the total saving in 1985 automobiles can easily reach 2 MBPD. Incidentally, attainment of an average of 20 mpg versus the present 13.6 would alone yield 2 MBPD.[5] Improvements in truck efficiency will add another savings of 0.4 MBPD. Significant gains are possible in intercity passenger and freight moving equipment, procedures, containerization. These can amount to 0.7 MBPD.

Investment in better insulation for home and commercial buildings would save about 1.1 MBPD, because space heating and cooling is a major area of energy use. Higher efficiencies can be obtained in equipment for home and commercial use amounting to 0.4 MBPD. Examples are conversion of one-third of incandescent lamps to fluorescent; improved air conditioning, heat pumps, and heating systems; and more efficient appliances.

Improvement in industrial processes can save another 1 MBPD. A major area would be the expanded use of the basic oxygen process for making steel and improvements in aluminum-refining processes. The FEO foresees the Btu's consumed per product in manufacturing dropping 2 percent per year between now and 1985, compared with 1 percent per year over the past five years.

ESTIMATED DEMAND REDUCTION

Considering the above, the Task Force estimates that a realistic target for reduction of demand is about 8 to 9 MBPD by 1985.* This target can be compared with savings projected by the Shell Oil Company of 3.3 MBPD by 1980 and 8.5 MBPD by 1990.[5] An illustrative breakdown of the Task Force's target range is shown in the following table:

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*One member of the Task Force believes that, on the basis of studies performed at the Cal Tech Environmental Quality Laboratory, the reduction in demand could be as high as 12 MBPD by 1985.

ESTIMATED 1985 U.S. ENERGY DEMAND REDUCTION

Category	MBPD
By Conservation	
Industrial conservation measures	1.5
Transportation	
Lower speeds, car pooling	1.0
Airplane load factors	0.3
Space heating efficiency	1.0
By Use of Energy-saving Equipment	
Smaller, more efficient cars	2.0
Other transportation savings	1.1
Better building insulation standards	1.1
Residential and commercial equipment	0.4
Industrial process efficiency	1.0
Total conservation potentials	9.4
Less 15 percent for partial overlap	8.0

To achieve the above, the physical requirements would be the following:

- Convert the automobile population from its present 30:70 ratio of small to large cars to at least an average of 50:50 by 1985. This will require the production of 75 million lightweight automobiles in the next 10 years.
- Expand mass transportation facilities in large cities.
- Ensure that construction of 20 million required housing units have substantially improved insulation.
- Make industrial processes 10 percent less energy-intensive, on the average.
- Do without energy through economy measures and more efficient energy space heating like heat pumps.

Beyond this is the reduced dependence on oil through greater use of coal and nuclear fuel sources. In 10 years the pressure on petroleum fuel can be reduced substantially, provided barriers to direct use of coal and nuclear fuel for electricity are removed.

POSSIBLE GOVERNMENT ACTIONS

Many of the results above can be achieved through the normal working of the Nation's economic system. However, government can play an important contributing role through the following actions; indeed, government leadership may be the key to effective conservation achievements.

Life-cycle Costing. Government purchasing policy, such as on automobiles, could take life-cycle costs, including energy and appropriate time values for money, into account, instead of only lowest initial cost. Similarly, regulations such as FHA housing insulation requirements could embody such life-cycle energy costs. The FHA-financing basis could be expanded to include, as acceptable appraisal items, storm windows and doors, extra insulation, heat pumps, etc.

Transportation Systems. In grants and financial assistance to transportation systems, preference could be given to those plans that appear to be energy efficient and can use more abundant domestic fuels. For instance, coal and nuclear power can be used to power electrified railroads and transit systems.

Information Program. Government could continue to encourage voluntary actions to conserve energy. Specific suggestions on how to save energy or substitute more abundant energy forms for oil and gas could be widely disseminated. The public must be made aware of the long-term nature of our current energy problem, the economic and political implications of not regaining our oil and gas self-sufficiency, and the need to adapt to higher energy costs in the future.

Chapter 4

COAL

INTRODUCTION AND OVERVIEW

Coal and lignite are under-utilized fuels having a limited substitution capability for oil and gas and the potential for being converted to oil and gas. The need for increased utilization of domestic coal reserves has been cited in many studies.

Recoverable coal resources in the United States can provide decades and possibly centuries of fuel and hydrocarbon supplies to help meet energy demands. The technologies for mining, washing, transporting, and burning coal are well known. Coal can be converted into electricity, heat, gas, and eventually into heavy liquid and lighter distillates to serve essentially all of the energy-consuming markets.

On the other hand, the production and use of coal involves potential environmental problems arising from surface mining, air pollution caused by direct burning, and health and safety risks in underground mining. These problems affect the costs and availability of coal. Trade-offs are involved, which need to be evaluated carefully if this domestic energy resource is to be utilized at increased levels in the future.

There are several separable facets to the coal utilization program: These subprograms — coal mining, coal transportation, and coal-based synthetics — are discussed below. Coal-burning power stations are discussed in Chapter 5.

COAL MINING

Background

Relative to other fuels, coal has been declining in importance in the United States. This situation has been caused in part by interfuel competition from abundant supplies of low cost gas and oil. The result has been a climate unfavorable to large investment. Mine output declined by almost 200 million tons per year (TPY) from its peak production in the mid-1940's until mechanization, particularly in surface mining, arrested the decline in the 1960's.

Other forces also began affecting the marketability and costs of coal. Environmental constraints appeared in the form of air quality regulations, and new strip mining regulations were promulgated. More stringent mine safety and health laws and persistent labor problems increased coal mine operating costs and decreased productivity.

The pattern of production and consumption in 1973 is shown in the following table:

1973 ESTIMATED COAL FLOWS

Source	Output (MTPY)	Markets	Consumption (MTPY)
Eastern underground	300	Power generation	370
Eastern surface	240	Coking	90
Western surface	60	All other	80
Total	600	Total Consumption	540
		Exports	60

Today, coal still faces significant constraints on growth. Uncertainties concerning the future cost of competitive energy forms, particularly imported crude oil, have made some consumers reluctant to sign long-term purchase contracts and have discouraged opening of some new mines. Uncertainties about proposed new surface mining and restoration regulations have held up new mining operations, particularly in the West, from where most of the future increase in production must apparently come. The scarcity of water in the West and environmental concerns about regional effects of surface mining are inhibiting factors. In addition, there are coal mining labor problems, including a current shortage of underground miners and mining engineers, making rapid expansion of production more difficult. Finally, the number of old mines abandoned because of depletion of their reserves and because of new safety requirements will continue to grow.

Estimated Production Increases

Despite all of these problems, the Task Force felt that given sufficient incentives, it is within the capability of the coal industry to expand mine production by about 660 MTPY in the next 11 years along the lines suggested in the following table:

ESTIMATED 1985 COAL FLOWS

PRODUCTION			FORM	
Source	1974-1985 Additions (MTPY)	1985 Production (MTPY)	Fuel	1985 Input (MTPY)
Mine depletion	(200)	—		
Eastern underground	280	480	Coal solids	950
Eastern surface	60	220		
Western surface	520	560	Synthetics	310
Total	660	1,260	Total	1,260

Historic mine depletion and replacement rates suggest that about one-third of the existing capacity (200 MTPY) will be replaced by 1985 with new mines in about the same proportion to the current type of production. The added new production is expected to come largely from western surface mines and eastern underground mines. Eastern surface mining should experience a slight decline because of lack of new surface reserves and legal restrictions on mining steep slopes. Eastern underground mining need only expand by about 60 percent if western surface mine production could be increased tenfold. The Task Force judged these to be rather realistic goals under the proper conditions. The logic behind this judgment is that western coals are in thick horizontal seams near the surface and are generally low in sulfur. Furthermore, western coals are of the noncaking variety, relatively low in cost and, therefore, the most suitable for current synthetic fuel processes. Surface mining yields the highest productivity per man-hour, important in a labor-scarce industry; and economic recovery of a greater percentage of the available coal is higher in the West than in either surface or underground mines in the East, giving western mines an economic advantage.

The reasonableness of the anticipated growth in western coal production can be judged from the fact that the necessary equipment for a 100 MTPY expansion of western mining is already on order and should be in-place within 5 to 6 years.[8] The additional equipment to achieve the desired growth should be forthcoming with proper incentives.

The magnitude of the projected increase in coal production can be grasped better if the numbers are translated into physical facilities to be added. Listed below are the kinds of actions that would be needed to achieve the estimated 1985 production levels.

- Develop 140 new 2-MTPY eastern underground mines.
- Develop 30 new 2-MTPY eastern surface mines.
- Develop 100 new 5-MTPY western surface mines.
- Recruit and train 80,000 new eastern coal miners.
- Recruit and train 45,000 new western coal miners.
- Manufacture 140 new 100-cubic-yard shovels and draglines.
- Manufacture 2,400 continuous mining machines.

Stated another way, on the average one new deep mine and one new surface mine must be brought into production every month for 10 years. In contrast, only 13 mines of greater than 2-MTPY production were opened in the 10 years from 1960 to 1969. In 1971, there were only 25 mines operating that were larger than 2 MTPY and only 3 of these exceeded 5 MTPY.[9]

The industrial capacity to manufacture large (80-100 cubic yards) power shovels is a potential bottleneck in the development of surface mines. There are only two manufacturers and both are currently quoting deliveries in the first quarter of 1979. Today's total industry capacity has been estimated at about one shovel per month, which would have to be expanded if these goals are to be met.

It is worthy to note that the estimated 1985 production of 480 MTPY for eastern underground mining is approximately the same as it was in 1940.

To increase the coal mining capacity from its current level of about 600 MTPY to a level of 1,260 MTPY would require large capital expenditures by the industry. In terms of 1974 dollars, the expansion cost would be on the order of $21 billion. To provide such capital, cash flows would need to increase and the market outlook would need to be stable and promising for a substantial time period, say 30 years. It is probable that average coal costs need to rise by $4 to $6 per ton in order to permit recovery of these capital costs.

Government Actions

Any program to expand the domestic coal mining industry rapidly would require the following steps to be taken now:

- Market forces. If private capital is to be used, the energy market would need to set a coal price that is sufficient to encourage needed investments in new coal mines.

o Stability. The financial risk of sudden changes in government treatment of competitive energy sources could be reduced by developing and adhering to a long-term U. S. energy policy. Mine operators should be expected to assume economic and technological risks; but, if they are to be encouraged to increase mine production to feed new power plants and synthetic fuel plants, they need early definition and stability in laws and regulations. Examples include sulfur dioxide emission standards (short-term variances will not lead to new mining capacity), surface mining restoration standards, and oil import policy.

o Western federal lands. Federal coal-bearing lands would need to be opened for leasing in 1974, with no impairment involving surface ownership or lease. The lead times for equipment and materials are long, and lands need to be made available in time to allow orderly development. Mechanized surface mining of western noncaking, low-sulfur coals using block-and-cut methods for minimum environmental problems perhaps offers the fastest way of increasing domestic coal production.

o Mine-operating regulations. Trade-offs of standards and criteria for design and operation of mines would have to be made to meet short-term national demand. Some relaxation of desired air and land quality may have to be considered now, with corresponding timetables for improvements later in the 1970's and 1980's to achieve the Nation's long-term environmental goals. Uncertainties brought about by pending changes or retroactive changes on projects underway serve to delay expansion programs and discourage new projects.

COAL TRANSPORTATION

Background

About one-half of all coal currently moves by rail, often in unit trains of 10,000 tons or so, and usually over distances of less than 500 miles. Flows per track often reach 2-3 MTPY.

In addition to rail movements, another 20 percent of the coal moves from mine to market via inland waterways, sometimes in dual-mode systems with both rail and barge movements. The transportation pattern for coal in 1973 was approximately as shown below:

1973 ESTIMATED LONG DISTANCE COAL MOVEMENTS

Transport Mode	MTPY
Railroad	400
Inland waterway	150
Slurry pipeline	5

Coal from eastern mines will continue to move to markets by rail and barge, and eastern mine-mouth power plants will continue to send out energy by high-voltage transmission systems. However, the problem of moving western coal to markets 1,000 miles or more away is a formidable one. For distances more than about 500 miles, costs for hauling coal overland tend to increase linearly with distance.

To be sure, much of the coal produced in western mines will move by train, train-barge, and train-barge-train systems to major consumers. However, trackbeds need frequent repair and upkeep, and existing railroad trackage has a practical saturation point. Beyond this point, new expensive signaling and dispatching systems will need to be added to existing rights of way, or new lines will be needed to absorb the increase in coal haulage from these western mines. It does not seem likely that railroads and barge systems alone can accommodate these possible coal flows from the West. Because of these factors, it is likely that pipeline systems will be a strongly growing competitor to rail systems. Such pipelines will occur in three separate forms: slurry, gas, and liquid. Present estimates of gasification costs range from $1.25 to $1.50 per million Btu, excluding the cost of coal and transportation to market. These costs should be compared with less than 60¢ per million Btu delivered costs for slurry pipeline or rail-delivered coal to the Midwest market. Therefore, gasification is not even remotely economical for power generation. Its application will be for domestic use through existing extensive natural gas distribution networks. Currently, no developed process exists for economical coal liquefaction, and so syncrude pipelines are not as yet in contention for western coal. The remaining pipeline alternative is coal slurrying.

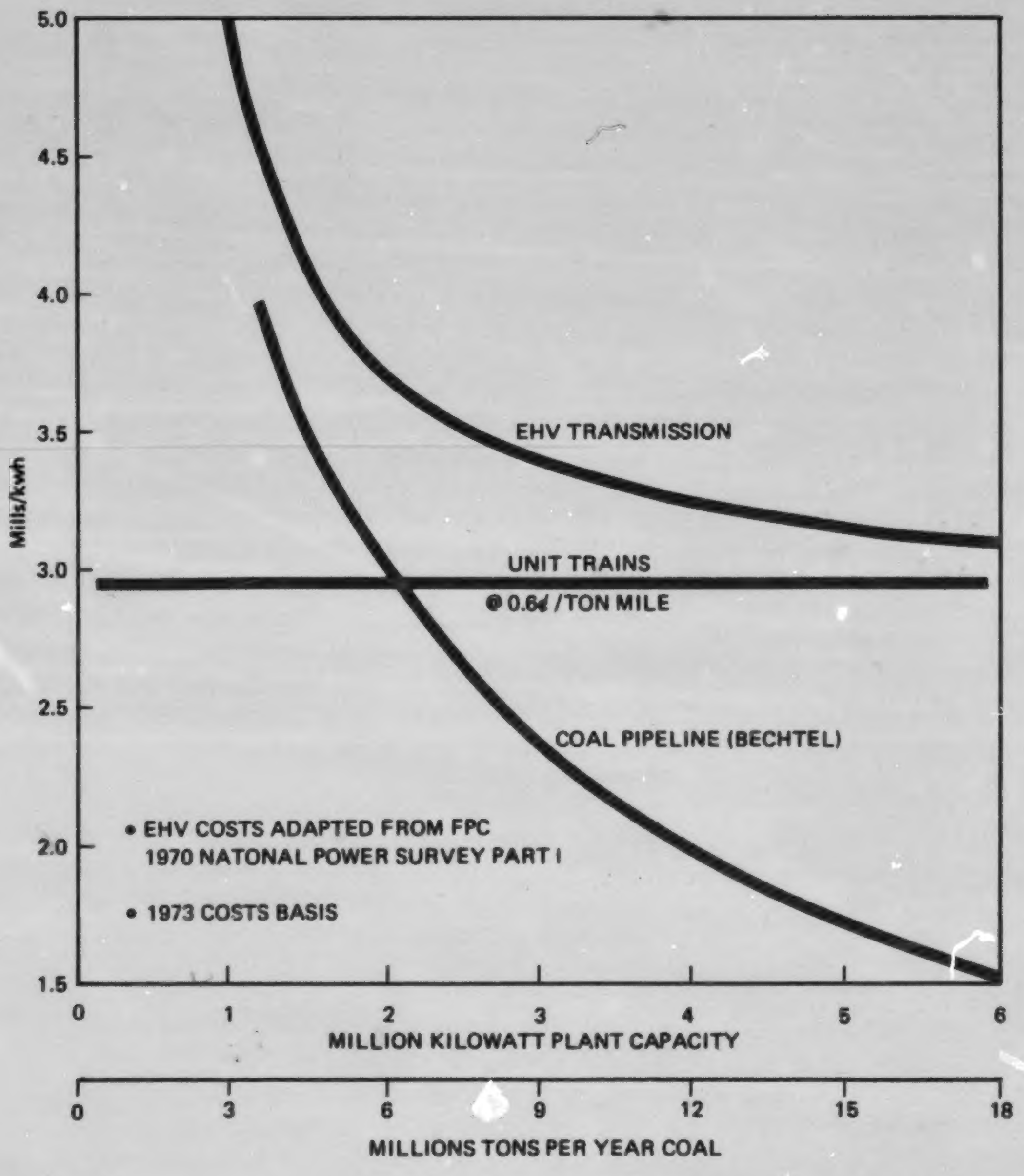
Coal slurry pipelines are an attractive way to supplement the growing transportation needs for western coal. One 280-mile-long coal slurry pipeline capable of moving 5 MTPY has been operating quite satisfactorily in the Southwestern United States, and a new 25-MTPY line nearly 1,000 miles long is currently under design. In intermodal competition for energy movements, there are trade-offs among available water supply, operating staff, disposal of water, escalation sensitivity, waterway availability, and system flexibility that will determine the mix of train-barge systems versus pipelines.

Transportation of electrical power by extra-high-voltage ac transmission becomes subject to instabilities at great distances. High-voltage dc systems are economical over long distances, but ac-dc conversion costs are high and no major system exists as yet over 500 kv in the United States.

Figure 2 shows a comparison of the alternative practical modes of coal energy transportation to eastern electric power markets from western coal mine.

Shortages of locomotives, gondola cars, and hopper cars are apparent even now; and in many cases power plant or mine owners will probably want

FIGURE 2 COST COMPARISONS OF ALTERNATIVE MODES OF COAL ENERGY TRANSMISSION (for 1,000-mile transport distances)



to purchase their own rolling stock. Safety and environmental problems will probably increase as traffic increases on mainline trackage. All new overland transportation systems will need additional rights-of-way, new facilities, new crews, and new rolling stock.

Achievable Capacity Increases

The Task Force judged that the transportation system would be able to meet the requirements of a 660-MTPY mine output increase by these multiple approaches. It should be noted that, of this total increment, only 400 MTPY is the increase in coal to be delivered in solid forms; the balance in growth is to be utilized for synthetics near the mine. It was judged that most of the new mine production capacity in the East probably would be served by unit train and inland waterway systems, even though both of these capabilities would need to be expanded substantially.

In the West, slurry pipelines were judged likely to make significant inroads on train-barge systems for new haulage capacity beyond the maximum that could be handled by the existing rail systems. This conclusion is founded on the automated, continuous, hidden nature of pipelines; their multiple land-use capability; their ability to operate one-way without empty returns; and their relative economics. Environmental acceptability was judged to be greater with pipelines than with other forms of surface traffic. In some western situations, the operation of slurry pipelines may be limited by available water supplies.

ESTIMATED 1985 COAL TRANSPORTATION

Transportation	1985 Total (MTPY)
Eastern rail and barge systems	650
Western rail and barge systems	200
Western coal slurry pipelines	100
Syngas pipeline (after conversion loss)	100

A comparison of these estimates with the 1973 transportation pattern shows that the Nation's rail-barge coal haulage capacity would need to increase by 300 MTPY or about 50 percent and pipeline capacity would have to increase by about 200 MTPY by 1985.

This estimated mix of coal transportation systems can be better visualized by considering their physical meanings. Using rough averages, such an increase in haulage capability, could involve:

o Construction of 60 new 2-MTPY eastern rail-barge systems of 100 to 500 miles each.

o Construction of 70 new 3-MTPY western rail-barge systems of 1,000 to 1,200 miles each.

o Construction of 4 new 25-MTPY slurry pipelines of 1,000 miles each.

o Construction of 2 new 2.5 BCFD gas pipelines of 1,000 miles each.

o Manufacture of 8,000 railroad locomotive units.

o Manufacture of 150,000 gondola and hopper cars, each of 100-ton capacity.

There is currently a temporary shortage of open top hopper cars. The number of open top hopper cars declined from 480,000 in 196[illegible] to 388,000 in 1969. Although average car capacity increase from 60 tons per car in 1960 to 72 tons per car in 1969, the aggregate capacity declined. This situation created a severe shortage of this type rail car and resulted in deliveries being currently at nearly two years.[10]

Possible Government Actions

Expansion of the transportation system to carry 800-MTPY more coal over the next 12 years could be enhanced if the following actions were taken in 1974:

o Railroads. Financial assistance would probably be needed to improve mainline trackage and signaling systems. Assistance in helping provide grade-separated highway crossings could be of material benefit to affected communities.

o Waterways. A program could be undertaken to help ensure that inland waterway systems have sufficient capacity to absorb a large potential increase in coal movements.

o Rights-of-Way. Rights of eminent domain could be established and exercised to ensure that industry will be able to obtain rights-of-way for railroads and pipelines expeditiously. The possibility of using interstate highway system right-of-way for energy transport by rail and pipeline could be considered.

COAL-BASED SYNTHETIC FUELS

Background

Liquid fuel was commercially produced from coal in Germany between

1930 and 1945. The most recent plant built for liquefaction is in South Africa and has been operating successfully for more than 15 years.

The process technology in Germany and R&D activities in the United States have been extensively treated in other studies. The Task Force attempted to estimate what level of truly commercial production of synthetic coal-based fuels could be achieved within 10 to 12 years if adequate incentives existed. Only technology that is ready or nearly ready for commercial application and is economically acceptable is considered in this report.

Economics are difficult to define sharply, but coal-based synthetics probably will have importance as future price setters. On one hand, commercial production of coal-based synthetic gases or liquids would set a ceiling on the value of imports or even marginal wells at home; but undue haste toward synthetics could cause premature commercial production, which could lead to unnecessarily high costs for synthetics, with the result of inviting others to raise natural fuel prices by reason of an incomplete technology.

In developing a synthetic fuel industry, prudence is a major requisite. Under no conditions could it be built up fast enough to relieve supply problems in the 1970's or in the early 1980's. However, it will be important in the late 1980's and beyond. The cost of investing too heavily now in an immature technology could be burdensome later. Cautious optimism is desirable.

Gasification of Coal

High-Btu Gas. Gasification is the key processing step for conversion of coal to synthetics. Two, possibly three, processes of German origin are available for immediate commercial application. In addition, there are five or six different gasifiers under development in the United States by government and industry. However, no U.S. process can be considered for wide-scale commercial use until it has been demonstrated at nearly full scale; this cannot be accomplished in less than 4 to 5 years.

Furthermore, the extensive studies undertaken by others suggest that economic improvement of these new processes over the present Lurgi process probably cannot exceed 10-15 percent, assuming that all forecast improvements are achieved, which must remain doubtful. The Task Force, therefore, assumed that full-scale methane-from-coal plants based on the Lurgi process and perhaps others can contribute to the energy supply in a meaningful way by 1985.

Medium-Btu Gas. In addition to high-Btu gas, there may be another market currently served by natural gas, where a leaner gas might be acceptable. Such lean gas can vary from 300-Btu/CF mixtures of CO and H_2 only, to 500-Btu/CF mixtures with additions of methane. These are the "raw" gases available from any of the demonstrated gasification processes, including Lurgi, Koppers, and Winkler.

This lean gas market could include power plants now fired by oil or gas and not convertible to solid coal. It is possible to convert these units, and many industrial plants, to such medium-Btu coal-based gas and to remove sulfur from the gases before or after burning. But there are economic problems in piping medium-Btu gas over any but short distances. There is also a loss in thermal efficiency for gasification compared to direct coal burning. For the even lower heating value producer gas (175 Btu/CF), a key concern in conversion from oil/gas to coal firing is the 30-35 percent boiler derating associated with the use of this lean fuel that results from the addition of nitrogen to the gas. The merits of diverting natural gas from power plants by medium-Btu syngas versus direct manufacture of high-Btu syngas are speculative. If medium or low-Btu gas finds a market, it will probably be in firing new combined-cycle power plants or in converting existing oil/gas power plants in the southern and southwestern parts of the country.

Liquefaction of Coal

With vast reserves of coal in the United States and with the great demand for liquid fuels, one of the most important questions needing an answer is that concerning prospects for conversion of coal to liquid fuels.

The Task Force considered this question and concluded that, while there could be a number of demonstration plants each producing perhaps 20 to 40 thousand barrels per day of oil from coal by 1985, there is no rational way by which substantially larger amounts of production can be achieved by that date. Even this magnitude of production would require an intensive development program. By the early 1990's, the results of such a program could be commercial production of oil from coal on a scale of millions of barrels per day. If this is to be achieved, it is of great importance to begin promptly. The reasons for this timescale are both technological and economic.

Because coal liquefaction has often been advanced as a method for making large amounts of gasoline and heating oils, a detailed analysis is provided to establish an informed perspective.

The two alternate routes to liquid fuels from coal, hydrogenation and gas synthesis, are well described in the literature. Both were large-scale operations in Germany between 1930 and 1945. Most of these plants were based on the hydrogenation concept, because it is the inherently more efficient system.

These technologies as they exist today would produce synthetics only at price levels well above those expected to represent future world price levels for oil. However, there is a good probability that, given an adequate effort, new R&D programs in the United States could yield lowered synthetic liquid fuel costs. It could thus be damaging to a viable synthetics industry to proceed to large-scale coal liquefaction based on currently available technology.

It should be recognized, furthermore, that for the last 30 years the preferred German system, direct hydrogenation, has not been used; no plants have been built and none operated. It is quite doubtful that adequate knowhow still exists to resurrect this technology without literally reinventing many of the technological details needed to build and operate a full-scale coal hydrogenation plant even of the 1940's design.

The situation is different for the Fischer-Tropsch gas synthesis process. A very up-to-date Fischer-Tropsch liquid-from-coal plant has been built in South Africa and is operating today. While it is a small plant of 7,000 BPD capacity, this technology is available now. The production costs are quite high, however.

Even though the gas synthesis process has now undergone significant improvements over the World War II German technology, it remains the conclusion of the Task Force that the desirable process for a U.S. liquefaction industry should be an improved technology for direct hydrogenation of coal.

Several avenues toward such improvements are known and have been explored for a good many years. However, these new concepts have not been pursued to the point where commercial plants can be built. The very costly prototype or demonstration phase of these new systems has not been undertaken, because the prevailing prices of crude petroleum do not provide an economic incentive.

New Technology. Hydrogenation as a route to liquid fuels from coal can be practiced in a variety of configurations; however, one key ingredient remains the same for all, i.e., hydrogen. Hydrogen is produced from water and coal or coal residues by gasification. This step can be safely based on the existing gasification technology.

All hydrogenation systems involve the addition of hydrogen to a coal substance at high pressure. German operations used between 3,500 and 10,000 psi. New processes are expected to utilize between 2,000 and 3,500 psi, representing a major advance in technology.

However, even at the lower pressures, this is a very demanding processing step in terms of special equipment and metallurgy; and it was the German conclusion, therefore, that wherever possible the coal should first undergo a feed preparation step to produce an optimum feed for the hydrogenation system. This included carbonization or extraction (even ultra cleaning of coal) to reduce the serious erosion and corrosion problems resulting from the introduction and removal of ash and unreactive coal in the costly hydrogenation reactor.

This choice of processing sequence must still be made, and the alternative new systems proposed for development can conveniently be grouped into (1) those treating coal directly with hydrogen at high pressure and in the presence of effective catalysts, and (2) those where coal is first processed to yield tar or extract for subsequent hydrocracking of the raw liquid under the more extreme conditions.

Alternative systems have been proposed for these feed preparation steps and for the manner in which the high-pressure catalytic hydrogenation is conducted.

Product Quality. Another dimension of the problem relates to the quality of the liquid fuel that is sought. Hydrogenation, in contrast to the Fischer-Tropsch synthesis, readily permits a wide choice in the characteristics of the final product. Hydrogenation is very flexible, and the R&D program should cover this dimension.

For certain coals and for certain local air pollution regulations, it may be possible to limit hydrogenation to a single, noncatalytic step, albeit still at high pressure. This may yield a reasonable low-sulfur, low-ash, solid fuel (400° F melting point) that can serve part of the market. For most applications, a more extensive treatment will be required, since many power plants are located in urban areas where less than 0.3 percent sulfur fuel is mandatory.

Finally, it is important to consider the large distance of the most desirable U.S. coal reserves from the market, which encourages conversion of coal into more easily transported forms near the mines.

R&D Needed. From the foregoing, the Task Force concluded that a desirable R&D program would require alternative process developments in order to test these concepts on a scale adequate to obtain information on the economic viability and performance of each system.

Most of these alternatives have been tested on laboratory scale (less than 1 TPD), and some have been or are about to be tested in units ranging from 5 to 75 TPD. It is possible, therefore, to move soon into the prototype plant phase where the final technological development short of full commercial-scale operation can be completed.

The processing of solids differs fundamentally from that of liquids in that operations are far more difficult to define precisely, and this results in a much more difficult extrapolation problem. This is particularly true of coals, which have a wide range of physical and chemical characteristics. Where a well-explored and understood chemical process is involved, it is possible to move directly from a laboratory test unit to full commercial plant. This is simply not practical when handling coal.

Coal hydrogenation involves a large number of difficult technical problems in materials handling, catalysis, and solid-liquid separation that can only be defined and resolved in equipment-simulating the final commercial system. These problems differ significantly among the various hydrogenation concepts. Thus a series of prototype plants would be required.

The purpose of a prototype liquefaction plant is to confirm the process conditions for an operable system in equipment that can be scaled up to commercial size with minimum risk; a factor of two to four would be acceptable. Most of the new coal liquefaction processes being developed in the United

States are faced with the same general problems. The severity of each problem and the importance of its solution toward achieving overall technical and economic success will vary among processes. The general problems include:

- Developing practical ways to introduce coal into a high-pressure system.
- Maintaining solvent balance to assure that enough good quality solvent is generated to slurry the coal feed.
- Defining the reactor system and the scale-up parameters for design of an operable and efficient commercial reactor train.
- Defining construction materials that will retain their integrity in a hostile atmosphere under severe temperatures and pressures.
- Defining equipment to reduce pressures from 3,000 psi to much lower levels.
- Defining equipment to achieve satisfactory solids separation from liquids and gas at high temperature.
- Establishing ways to maintain catalyst activity.
- Defining and solving environmental problems.

Each of these elements must be tested in a fully integrated facility to establish the effect of interactions and to test the effects of process changes. The cheapest, easiest, and quickest way to achieve integrated operation is in a prototype plant rather than in a commercial unit. The basic advantages are:

- Changes to make the plant operable can be made more rapidly and at lower cost because smaller equipment is used.
- More alternatives can be tested because their total impact on cost and schedule is less.
- The prototype plant can be designed to process and test more than one coal.
- The failure to recognize a potential environmental problem in the prototype plant has a less severe effect on the surroundings because of the relatively small size of the facility.

Not the least advantage of having a series of parallel prototype plants of intermediate size (300 to 1,000 TPD) is the ability to operate these plants on a variety of coals that will respond in different ways to each process. If the plants are too large, it may be impossible to cover the great variety of U.S. coals in the test program simply for economic reasons.

Finally, regarding the appropriate size of the prototype plants, the largest of the German hydrogenation reactors processed around 500 TPD, which is a small figure compared to the projected needs for synthetic liquids. Current United States development hopes to reach 2,000-3,000-TPD reactors at least in the first generation of commercial liquefaction units. Even in these sizes, multiple process trains will be required.

The proposed prototype plants seem to fall somewhere between the demonstrated German capacity and possibly two to three times that rate. This appears prudent to the Task Force. Satisfactory results at that scale will permit a safe extrapolation to the full commercial sizes in the range from 2 : 1 to 5 : 1, depending on the process; in fact, certain other crucial items of equipment (heaters, pumps, exchangers) would require no extrapolation at all, since multiple units would inevitably be needed.

Program Cost. Each prototype liquefaction project would cost between $75 and $125 million. It is likely that each project would require substantial government support in addition to private capital. In this regard, the Task Force urges that government sponsorship be designed to encourage the establishment of possible proprietary positions in terms of patents and know-how for private industry involved in the effort. The expertise required for successful conduct of such a program is simply not to be found anywhere except in the private energy industry; and in order to maintain a competitive spirit and draw the best technical talent to this program, some reward for success must be available to those who commit themselves to these projects. The Task Force believes appropriate arrangements can be made to take advantage of private enterprise expertise and still safeguard public interest.

Conclusion. The Task Force believes that an aggressive liquefaction development program should be a major cornerstone of the long-range supply of liquid fuels, even though the total volume forecast for production by 1985 is quite small relative to other fuels.

Methanol. The production of methanol is a special case of liquefaction, similar to the Fischer-Tropsch process and to the production of synthetic methane. The cost of this fuel delivered to consumers will probably fall close to that of coal-based methane because of methanol's low transportation cost. Methanol is produced now but is not generally used as fuel; and large-scale application in transportation, for example, would need to be preceded by additional major use tests in the United States. Other currently feasible uses are as fuel for peak-load gas turbines and as replacement of fuel oils or low-pressure gas for industrial and home heating.

Production of methanol from coal is as well or better demonstrated than production of methane. The Task Force, therefore, estimates that some methanol could be included in the range of coal-based synthetic fuels by 1985, although the market outlook is quite uncertain.

This then illustrates the position of synthetic fuels from coal:

- Methane from coal is ready for immediate commercial application.
- Methanol is almost as ready, but commerical-scale uses to take

advantage of lower transport costs are yet to be developed.

- Liquefaction processes using hydrogenation are not ready for present use, but R&D started immediately and generously funded could lead to large-scale use starting in the late 1980's.
- Coal processing for power plant use, including gasification, liquefaction, stack-gas scrubbing, and fluid-bed combustion, will find commercial use due to the varied requirements of the power industry (See Chapter 5).

Estimated New Production

In view of the large capital requirements and the high element of risk involved with all synthetic fuels from coal, the Task Force concluded that the estimated maximum production in the next 10 to 12 years might include the following facilities:

- Construction of 20 new 250-million CFD methane-from-coal plants.
- Construction of 8 new 40,000-BPD methanol-from-coal plants.
- Construction of 10 new 30,000-BPD coal liquefaction plants.

The proposed program is summarized in the following table. The Task Force felt that this would be an ambitious program involving some $16 billion to $22 billion of capital expenditures.

ESTIMATED 1985 COAL-BASED SYNTHETIC FUELS
(Based on Western Coal)

	Input[a] (MTPY of Coal)	Production (MBPD)
At Mine		
High-Btu gas	150	0.8
Methanol	60	0.3
Syncrude	50	0.3
Total	260	1.4
Medium-Btu gas	50	0.3

[a] Based on use of 8,500 Btu/lb western coal.

Possible Government Actions

If a domestic coal-based synthetic fuels industry is desirable, it would be enhanced by the following government actions:

o Approval of Gasification Projects. The government could assist companies who have announced methane-from-coal plants in achieving prompt approvals for construction.

o Sponsor Liquefaction Plants. Because of the high risks involved in extrapolation of this technology, partially government-financed, competitive parallel demonstration projects could be undertaken based on logical industrial program plans.

o Allow Proprietary Patent Positions. If the best technical and managerial talent is to be attracted to the creation of a vigorously competitive synthetic fuel industry, proprietary data, patent rights, and know-how should be safeguarded.

On the last point above, it is recognized that the government may be involved financially, particularly in the creation of coal liquefaction plants. If privately developed processes, as well as background data and know-how, are not protected, then industry will not be in a position to recover previous expenses. If foreground process assistance by the government threatens background data and know-how, industry having such process experience will not want to participate. Furthermore, wide dissemination of foreground and background rights and data seems inconsistent with establishing a vigorous, competitive industry.

The extent of government financial support could be reduced, provided there is a willingness to so interpret the antitrust laws as to encourage cooperative R&D activities and thereby spread the risk, while preserving competition during the production phase.

Chapter 5

ELECTRICAL POWER GENERATION

INTRODUCTION AND OVERVIEW

Electrical power generation is such an important converter of primary energy that it is appropriate to single it out for special discussion. Electric power generation has been increasing at a rate of almost 7 percent per year, whereas the rate of increase for all forms of energy in the United States is about 4 percent per year. In 1973, power plants consumed the following portions of the U.S. primary energy resources.

POWER PLANT PRIMARY ENERGY CONSUMPTION, 1973

Resource	Percent Consumed in Electricity Generation
Coal[2]	64
Uranium	90
Hydro and geothermal	100
Oil and gas[2]	13

Some existing power plants have a substantial capability for primary fuel substitution, and there are several fuel choices for new generating units. Such fuel substitution can help place more of the Nation's energy use on abundant domestic fuels -- that is, nuclear, coal, and renewable resources.

The overall power generation picture will be discussed in several sections as follows:

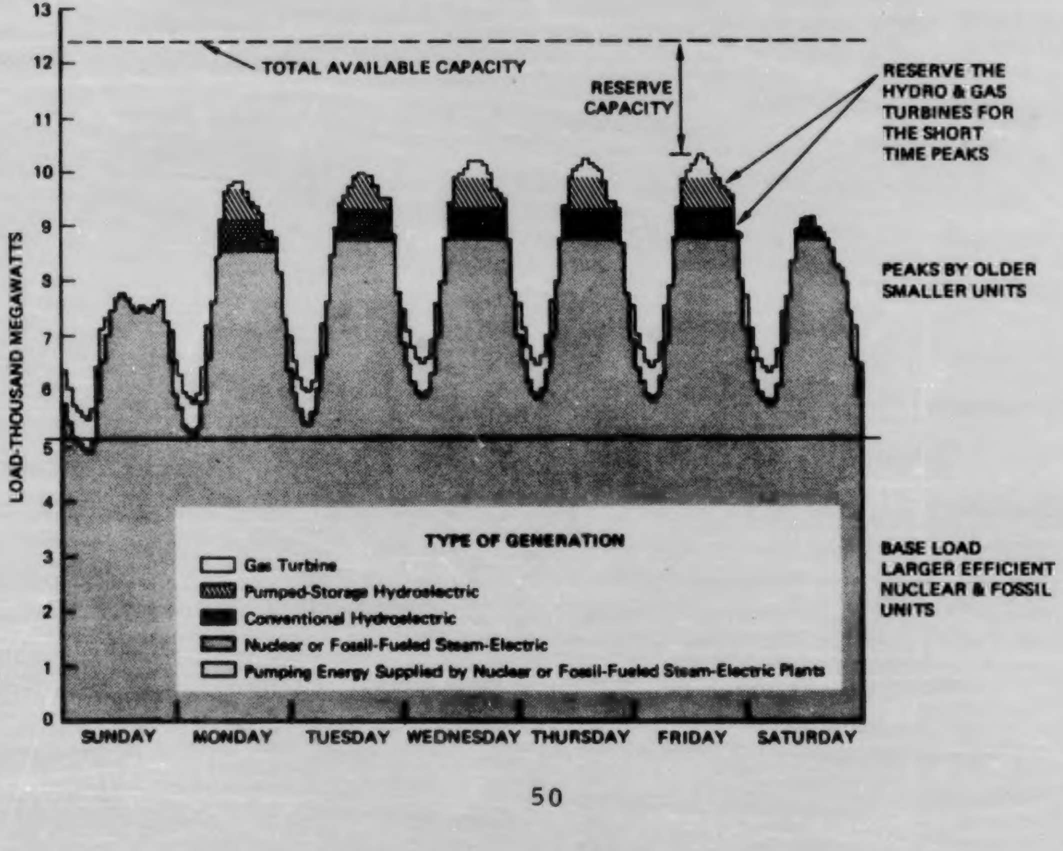
- o Coal-Fired Power Stations
- o Nuclear Power Stations

- Nuclear Fuels
- Renewable Resources
- Oil/Gas-Fired Power Stations
- Transmission and Storage

Because there is no substantial capacity to store electricity, supply-demand relationships are measured in essentially instantaneous terms. Energy consumption (Kwh) and peak capability (installed and available kw) are separate subjects, and both are important. Daily, weekly, and seasonal variations in load affect both of these and require that some power generation units be predominantly steady-state (base-load), while other units vary with load swings (cycling), and yet others are started up solely to meet short-term peak demands (peaking).

Typical domestic variations in weekly electricity demand are shown in Figure 3. In addition, there are wide variations in the hourly load and substantial changes in seasonal loads. For instance, in some parts of the country, because of air conditioning, the summer peak load is 40 percent greater than the winter peak.

FIGURE 3 U.S. TYPICAL WEEKLY ELECTRICITY DEMAND



The capacity required to satisfy such peak loads is greater than the base load, and any steps to make demand more uniform would make the overall generating system more economical.

Utility economics govern the allocation of plant types to these various services. Loading of the grid usually occurs by scheduling the largest and lowest-operating-cost generating units to serve the base-load energy requirements first and then adding smaller, less efficient units as required to meet the peak loads of variable duration. Hydroelectric power, despite minimal operating costs, is utilized more and more for peaking in many areas, because such capacity can be added economically even though overall generation is limited by fixed water storage.

For peaking plants, high fuel cost is much less important than low capital cost; while in base-loaded plants, low operating cost is the important parameter rather than low capital cost.

Of the installed capacity today, large coal-fired power stations are predominantly base-loaded, as are nuclear units. Oil- and gas-fired plants may serve as base-load sources in some parts of the country but more typically would serve a cycling function. Older coal-fired plants in some sectors of the country also serve the cycling function. In some areas gas turbines plus hydro units provide the peaking functions.

COAL-FIRED POWER PLANTS

Because demands on crude oil and gas are to be diminished, one major way is to stress nuclear, hydro, geothermal, and coal resources for our electrical power generation.

While coal-fired units have supplied both base-load and cycling functions, particularly in northeastern utility systems, modern coal-fired units have tended to become more inflexible; and the largest units today provide mainly base-load power. Growing particulate, sulfur, and nitrogen oxide stack gas emission controls have caused losses in both flexibility and availability. High degrees of superheat, high pressures, extreme water treatment, many stages of feedwater heating, cooling towers, precipitators, and now SO_2 removal process equipment all have combined to make the modern coal-fired station a complex process plant.

Some years ago, the promise of low fuel costs and the clean air aspects of nuclear plants began to attract attention from the electric utilities. In addition, the utilities foresaw a potential freedom from the month-to-month dependence on continued flow of coal from the mines and over the railroads. With strengthened environmental standards in the offing, new coal-fired plants began to suffer from serious inroads made by new nuclear plant orders and accelerating conversions to oil and gas firing.

As regulatory and equipment delivery delays began plaguing the nuclear construction program and the opposition to burning high-ash, high-sulfur coal gathered momentum, more orders went for oil-fired stations to fill the gap being rapidly created. The crippling black-out in the Northeast in 1965 led to increased grid system interconnections, and the rising summer peak loads in later years led to greater numbers of gas turbine peaking units. All of these factors increased the moves toward gas and oil firing, until natural gas producers began to refuse to renew or make long-term gas contracts and until the 11-nation Organization of Petroleum Exporting Countries (OPEC) began serious oil price increases. Predictably, the recent oil embargo has turned many utilities back toward coal firing and, because of air pollution regulations, toward western low-sulfur coals.

1973 ESTIMATED COAL-FIRED POWER STATIONS[11]

Type	Gwe Installed
As built, eastern coal	163
As built, western coal	10
Conversions to oil firing	(30)
Remaining coal	143

Since the mid-1960's, a number of coal-fired stations have been converted to oil firing. These changes occurred at first because of economics, but accelerated later because of stack gas emission standards regarding sulfur. Some 400 units amounting to about 30 Gwe have been converted to oil in the past 10 years, and about 20 percent of these have either sold off their coal storage pile land, built additional units on the land, and/or removed coal- and ash-handling equipment.[11] The result is that these latter conversions are essentially irreversible now.

In addition, there are existing units that, although they still have multiple fuel-burning capability, cannot obtain approval to revert to coal firing because of environmental regulations. Because the law requires use of the "best possible technology," there has occasionally been a refusal to allow coal burning of any sort, including low-sulfur coal, even though the sulfur content may be nearly the same as that of the oil currently being burned. The result is that oil that could be diverted to other liquid petroleum uses continues to be burned.

One example is Consolidated Edison's Ravenswood plant, Unit No. 3, providing 1,000 Mwe in New York City, which formerly used 0.9 percent sulfur coal (equivalent to perhaps 1.25 percent sulfur oil) and in the winter of 1973-1974 burned up to 1.5 percent sulfur residual fuel oil part of the time. The city and Federal environmental agencies refused a request to convert back to coal. This decision, aimed at a marginal reduction in SO_2 emission, resulted in an additional fuel cost of about $100 million per year and also diverted almost 1 1/2 million gallons per day of liquid hydrocarbons from other purposes.

The Task Force takes no position regarding the merits of this particular decision but does want to stress that when trade-offs are involved, including health risks and other environmental effects, these trade-offs should be quantified and made known in terms the public can understand.

Rapid expansion in installation of new coal-fired stations will be hindered by some of the same problems that nuclear units encounter, namely, lack of water cooling, lack of approved sites, and restrictions on environmental emissions. Even in entirely rural areas and in well-ventilated air basins, coal-fired power plants are required to employ the same emission control standards and SO_2 removal processes that urban power stations are being required to use. The reliability of SO_2 removal units has not been demonstrated, but air pollution control authorities have been reluctant to grant waivers or variances for even short periods of time, regardless of meteorological conditions prevailing at the time. Thus, an entire major power plant may have to be shut down because of failure of ancillary equipment.

Because of this, the electric utilities have been reluctant to become dependent on SO_2 removal process equipment, which is not only expensive but also threatens the entire plant and system because of possible forced shutdowns. A great deal more effort must be applied to achieve a reliable system for use on coal-fired units. One way to increase the momentum toward this goal would be for the Environmental Protection Agency (EPA) to grant variances to maintain a plant on-line in case of SO_2 equipment failures and to sponsor considerably more effort toward developing reliable operating process equipment and regenerative units instead of throw-away processes. As oil prices increase, coal, even with SO_2 scrubbing equipment, will become more attractive.

Although SO_2 scrubbing systems have not yet shown demonstrated reliability on a commercial scale, it seems likely that practical processes can be achieved. Their importance can hardly be overestimated, since the current limits on SO_2 emissions provide a major stumbling block to wider use of coal for power. Stack gas scrubbing is expected to be more economical than the use of low-sulfur oil or synthetic fuels and would permit the desired substitution of coal for oil and gas to proceed more rapidly. It is one of the few things that can be done to improve domestic energy utilization without causing serious environmental problems. Adjustment of the rate structure to cover the cost of SO_2 scrubbing might help accelerate the development and use of such systems.

Another approach to controlling SO_2 emissions could be the intermittent control of stack gas emissions. Burning of higher-sulfur coal would be permitted only during periods when atmospheric conditions dilute the concentrations of SO_2 below the primary air quality standards. Although the effectiveness of this technique is controversial, it is a possible solution under certain favorable atmospheric circumstances and should be examined as to meteorological and environmental consequences.

Yet another approach to controlling SO_2 emission is the use of fluidized bed combustion in which a material, such as limestone, is used as a bed material. The bed is kept fluidized by the combustion air and by the flue gas resulting from the combustion of the coal. The limestone is calcined to lime, which reacts with the SO_2 and oxygen in the flue gas to form calcium-sulfur compounds. When used on a once-through basis, high limestone feed rates are required if SO_2 removal of 90 percent or more is to be achieved. Some method of regeneration of the calcium-sulfur compounds back to lime is desirable in order to reduce the solid waste disposal burden created by the high limestone feed rate.

While considerable technology already exists on fluidized bed combustion, demonstration of this technology for steam boiler application is just getting underway. A 30 Mwe atmospheric pressure unit is presently under construction and larger units are being designed. In contrast to some of the SO_2 stack gas removal processes, fluidized bed combustion can only be used in new boiler installations. This important limitation, coupled with its early stage of development, would probably limit the impact of fluidized bed combustion to the period well after 1980.

Estimated Installed Capacity

After study of the problems facing the coal mining, coal transportation, and power-generating industries, the Task Force concluded that coal-fired power plant additions by 1985 could amount to 180 Gwe, for a total installed capacity of 330 Gwe. Included in this total are 20 Gwe of oil conversions that could be reconverted to coal firing in the next few years if suitable variances or regulations can be administered to encourage this.

Some conversion of the oil- and gas-fired units across the Southern United States to intermediate-Btu gas made from coal could also be considered. Economics dictate that such coal be delivered to the consuming area and then converted to gas. The market forces that would influence such conversions are unavailability of natural gas, low-sulfur crude oil, or low-sulfur residual oils. The price of medium-Btu gas will not be low. Also, the use of gas from coal is less efficient thermally than the direct burning of coal.

On the other hand, power costs for cycling and peaking plants are not overly sensitive to fuel costs. This is one method of shifting more burdens onto coal at a cost less than that of converting coal to high-Btu pipeline quality gas. The Task Force estimated that a probable 1985 installed capacity for such medium-Btu conversions might be 20 Gwe and further observed that the technology is available now at commercial scale to effect such conversions. Some power unit derating may be involved.

ESTIMATED 1985 INSTALLED COAL-BASED PLANTS

	1985 Gwe Installed	1974-1985 Additions
Coal/lignite-fired steam	310	+167
Oil reconversions	20	+ 20
Medium-Btu gas conversions	20	+ 20
Total	350	+207

The magnitude of this expansion would be about $60 billion in new facilities and conversions by 1985. In physical terms, this would mean:

o Reconverting 5 oil conversion units per month for 4 years.

o Designing, constructing, and bringing on-line 2 new 700 Mwe coal-fired units per month for 10 years.

o Designing and manufacturing 24 new 700 Mwe turbine generators every year for 10 years.

o Designing and erecting 180 new 2.5-MTPY coal-fired furnaces.

o Purchasing and developing 50 new plant sites.

o Designing, constructing, and starting up 10 new medium-Btu gas conversion plants to supply 50 existing gas-fired units of 400 Mwe each.

These requirements are within present industry capabilities. The conventional steam turbine-generator business is a mature industry and no shortage of capacity is expected in this area. In 1972, the industry shipped a total of nearly 28,000 Mwe of turbine generators. Based on 1973 backlogs, more than half the industry capacity is estimated to be in units of 800 Mwe and larger.[12] The same conditions generally apply to the fossil fuel steam supply industry.

Possible Government Actions

If expansion of coal-fired power generating capacity is desired, it could be enhanced by the following government actions:

o Establish Variances. Air pollution agencies could establish a policy providing that under favorable weather conditions variances on stack emissions could be given where SO_2 removal process equipment reliability problems are encountered.

o Improve SO_2 Scrubbers. The government could help accelerate process design and reliability improvements in SO_2 scrubbers by carrying out additional competitive parallel design-supply-test programs with a number of industrial teams.

o Intermittent Control. Regulations could be adopted to provide (on a long-term basis in order to provide stability for coal supply and plant investments) that high-sulfur fuels, particularly coal, would be burned as long as the ambient conditions at ground level, as continuously monitored, did not exceed specified limits. If these were exceeded because of meteorological or other conditions, then the plant would be required to switch to low-sulfur fuels, reduce output, or shut down. Such plants would usually be designed with high stacks and other provisions for diluting the stack output and reducing ground-level concentrations of SO_2. Such provisions would require consideration of the hazards from sulfate production that might affect areas at a great distance from the power plant rather than the immediate surroundings.

NUCLEAR POWER STATIONS

After more than 30 years of research, development, and large-scale demonstrations, nuclear power plants are now being utilized on a rapidly increasing scale by electric utilities in the United States. Almost all nuclear units are so-called light-water reactors, although gas-cooled reactors are receiving increasing attention.

Background

Until about 18 months ago, Atomic Energy Commission (AEC) and industry projections of installed nuclear plant capacity were about 150 Gwe by 1980 and about 300 Gwe by 1985.[13] In early 1973, the Atomic Industrial Forum completed a study that indicated that 150 Gwe could be achieved by 1980 and 365 Gwe could be achieved by 1985 if positive action were taken on certain licensing and other issues.[14]

Little effective action was taken on these recommendations and, as a result, the estimates for both 1980 and 1985 have again been revised downward. New AEC forecasts project that under most likely conditions only about 100 Gwe of nuclear power will be in operation by the end of 1980, and only about 250 Gwe by 1985.[15] In terms of time, these slippages correspond to about 2 years by 1980 and about 1 year by 1985.

Just 5 years ago, about 6 years were required from inception to on-line power generation for nuclear units. Presently, lead times for new nuclear units have increased to 9 to 10 years. It should be possible to reduce these lead times once again to about 6 or 7 years, despite problems in obtaining equipment and material in a timely manner. Present orders do, of course, reflect current perceptions of lead times by the electric utilities. Expressed in terms of relative fossil fuel displacement potential, the 50 Gwe forecast difference in 1980 is equivalent to about 1.4 MBPD. Thus, this nuclear plant slippage is quite serious indeed.

NUCLEAR POWER STATIONS AT END OF 1973[16]

Status	Gwe
Units with operating licenses	25
Awaiting operating licenses	30
Construction permits granted and under construction	23
Construction permits pending and under design	60
Announced, but applications not yet filed	50
Planned, but not announced	ca. 20
Total	208

It seems clear that any policy seeking to minimize dependence on imports and to conserve fossil fuels must consider assigning a high priority to the acceleration of the installation of nuclear plants. As a condition for this acceleration, nuclear power plants as now designed, built, and operated would have to be recognized as adequately safe, environmentally desirable, and strategically necessary. Such recognition would eliminate the current practice of redeciding or reconfirming that same conclusion several times over for each individual project.

One of the serious problems of the nuclear power industry is the AEC licensing process. This procedure involves filing an application for a construction permit. Each application must be accompanied by a Preliminary Safety Analysis Report (PSAR) and an Environmental Impact Statement (EIS). These take about 3 years to prepare for a plant on a new site. The PSAR is reviewed both by the AEC licensing staff and the Advisory Committee on Reactor Safeguards (ACRS). When these and the environmental reviews are completed -- it usually takes about 2 years -- a public hearing is held at which the findings of these reviews are presented and intervenors are given an opportunity to challenge the findings.

The construction permit, when issued, allows the physical construction of the plant to proceed; and, when the plant is completed, essentially the entire process must again be repeated with submittal of a Final Safety Analysis Report (FSAR). Once again, public hearings are held before an operating license is granted. Even then, the license may not grant permission to operate at full power; and AEC inspection procedures after operation has started tend to make the plant unavailable for power operation a higher percentage of the time than seems reasonably necessary.

These procedures had their origins in the early days of rapidly developing and changing nuclear technology; and, while commercial nuclear power experience and know-how has matured to a major industry today, the licensing process has not matured with it.

For example, under current procedures there are multiple reviews of designs already reviewed and previously approved. Many design changes must be applied to plants already under construction or even already in operation. These changes usually have their origins in licensing proceedings on other projects. This practice, called "ratcheting," is disruptive; and many people in the industry feel that it is counterproductive to safety, as well as the schedules, costs, and public benefits.

Many people in the industry believe that reviews in detail by the AEC staff and the ACRS are counterproductive and wasteful of limited engineering manpower when applied to duplicate plants, twin units, or plants consisting of units, modules, or systems already reviewed and licensed by the AEC.

Estimated Capacity Increases

If the licensing problem can be ameliorated by more efficient procedures, the Task Force believes that about 125 Gwe might realistically be expected to be operating by the end of 1980. While the 365 Gwe postulated by the AIF no longer appears likely, it is believed that a determined effort could lead to 325 Gwe being in operation by the end of 1985.* This would displace the equivalent of about 8 MBPD of oil by 1985.

ESTIMATED 1985 NUCLEAR POWER CAPACITY

Type	1974-1985 Additions, Gwe	1985 Capacity, Gwe
Light water reactors	+280	305
Gas-cooled reactors	+ 20±	20±
Breeder reactors	Nil	Nil
Total	+300	325

Expressed in average physical facility terms, the addition of 300 Gwe of nuclear power by 1985 could involve:

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*One member of the Task Force believes that the maximum installed nuclear capacity at the end of 1985 will be no more than 150 Gwe, based not simply on delays caused by protracted hearings but on an assessment of the sheer magnitude of the task.

- Design and construction of an average of two to three new nuclear units per month for the next 10 years.
  - Fabrication and delivery of an average of 30 reactor pressure vessels and 30 turbine generator sets each year for 10 years.
  - Acquisition and approval of 10 to 12 nuclear plant sites per year for 10 years.
  - Recruiting and training of 30 to 40 thousand plant operators and maintenance personnel in the next 10 years.

Possible Government Actions

If it is desired to accelerate the nuclear power plant installation program, the Task Force believes that the most immediate problem is to accelerate the granting of construction permits already applied for and to facilitate the construction of those units already being manufactured and constructed. About 138 Gwe are already in the "pipeline" up to the licensing stage. The estimated installation of 125 Gwe by 1980 would be enhanced, if the following actions were taken by the government:

- Approve Generic Designs. Construction permits could be granted on demonstration that a proposed plant is a duplicate of one previously licensed or that it consists of systems or modules previously licensed -- with verification of details later.
- Reduce Retrofitting. More mature judgment and increased senior attention to design changes on licensed plants during construction could ameliorate this disruptive practice.
- Separate Antitrust Matters. Antitrust considerations could be separated from safety and environment reviews and treated separately.
- Grant Operating Permits. Operating permits could be granted upon certification that the plant has been built and tested in accordance with the construction permit without a new public hearing.
- Accept State and Locally Approved Sites. Sites that have been reviewed and approved by a state or local agency regarding environmental impact could be certified without further review, provided that the basic requirements of the National Environmental Protection Act (NEPA) have been satisfied.

In order to achieve 325 Gwe in operation by the end of 1985, it would be necessary to initiate an average of 25 new 1,200-Mwe units each year during the next 4 years and have these licensed and built together with those now underway. This is less than the rate of new orders during the past 2 years. The Task Force believes that this is feasible if the government gives particular attention to reducing the time periods required for preconstruction activities. Government actions, in addition to those already cited, that would enhance this would include:

- Preapprove Sites. Special boards or some comparable mechanism could be established to review proposed sites, assess environmental impact, hold public hearings on site-related issues, and render an approval-disapproval decision within a reasonable time, perhaps 6 to 9 months.
- Reduce Unnecessary Environmental Report Efforts. A more efficient review process could be achieved by reducing the volume of environmental data required, eliminating "baseline" data delays, reducing duplication of information, adopting uniform criteria, accepting generic reports, and eliminating multiple environmental reports.
- Adopt Standard Generic Design Procedures. The government could develop, based on modular generic designs for equipment and plants, a standard licensing procedure that would provide for standards and criteria for equipment, systems, arrangements, and materials.
- Reduce ACRS Reviews. The ACRS could be limited to reviewing new designs, major modifications or special problems, broad problems of definition, and consideration of new types of reactors and equipment.
- Revise Quality Assurance Procedures. Reevaluation of documentation and procedures for quality assurance and quality control to focus attention on important items could reduce the demands on trained personnel, shorten schedules, and lower costs without lowering quality of the product.

A final point should be made here. If the licensing period for nuclear plants was suddenly shortened by alleviating some or all of the constraints just discussed, we would be faced with an even greater manpower shortage than exists now, both in the field and in design offices. To alleviate field manpower problems, more rational quality assurance and quality control requirements are needed; and the frequent practice of retrofitting should be reduced. To help stretch engineering manpower, it would be advantageous to reduce unnecessary detail in regulatory questions as well as to reduce required design changes. If these steps are not taken, it is doubtful that available manpower would be capable of handling the work that would be thrust on the industry.

NUCLEAR FUELS

Rapid growth of nuclear power involves many questions relating to nuclear fuel--the provision of adequate supplies of fuel, usually as low-enrichment uranium dioxide clad in zirconium, and disposition of spent fuel, usually involving storage and transport to a reprocessing plant where the uranium, plutonium, and radioactive wastes are separated. In addition, there are questions not only with respect to storage and disposal of radioactive wastes, but also with safeguards against theft of fissionable or highly radioactive materials.

Uranium Mining and Milling

It has taken an average of about 8 years from the time uranium exploration is initiated until substantial production is achieved from new mines and mills. The variations from this average can be substantial due to uncertainties of exploration. There are few reasons to believe that this average can be shortened significantly in the future, and it may be lengthened if exploration is less successful. Domestic uranium concentrate (U_3O_8) production reached 17,600 tons per year (TPY) in 1960, but declined to about 13,000 TPY in 1973.

1973 ESTIMATED URANIUM MINING AND MILLING

Item	TPY U_3O_8
1973 production output	13,000
Standby capacity	5,000
Total capacity	18,000

The quantities of uranium needed in the future depend not only on the rate of increase in operating nuclear power stations but also on the amount of fissionable U^{235} remaining in the uranium tailings after enrichment. It also depends on whether or not plutonium recovered is used for enrichment in place of some of the U^{235}.

While the concentration of U^{235} in enrichment plant tailings is largely an economic question, the use of plutonium for commercial enrichment is currently prohibited by the AEC, which is examining the licensing questions involved in using plutonium-enriched fuel. The AEC has promised to resolve these by the end of 1974. This is extremely important, because an inability to count on plutonium recycle would increase future requirements for uranium and uranium enrichment by as much as 30 percent over the figures estimated above.

Although the situation is changing rapidly, the rate of uranium exploration has been very low, largely because of the depressed market. This has been caused by the failure of utilities to enter into long-term contracts for uranium which, taken with the long payout combined with high interest rates, have made speculative prospecting an unattractive gamble. Imports of uranium into the United States for use domestically have been prohibited, but with the proviso that imports would be allowed when a "viable" domestic uranium mining industry has been established. Recently, the AEC proposed to relax import controls on the basis of a graduated scale ranging from 10 percent for any one customer in 1977 to 100 percent in 1984. While this proposed action removes some uncertainties, many segments of the uranium mining industry feel that it is still unsatisfactory and raises further doubts about the stability and outlook for domestic uranium mining.

The importation of uranium would not be consistent with a concept of self-sufficiency. There are serious questions as to the amount of uranium that may be available for import, because nuclear power is growing rapidly in the rest of the world --at a rate about equal to that in the United States.

With 325 Gwe in operation at the end of 1985, uranium requirements in 1985 would be about 80, 000 tons, assuming use of plutonium recycle.

Production would need to be more than quadrupled by 1985 over the maximum ever achieved in the United States. In physical terms, this means that from 50 to 100 uranium mines of 1, 000 TPY or less must be opened in the next 10 years. These mines and the associated exploration and development programs, along with the associated mills, would involve an investment of about $5 billion.[17] Nevertheless, the Task Force judged that production of about 75, 000 to 85, 000 TPY of domestic uranium could be achieved.[*]

If it is desired to provide adequate uranium supplies and encourage expansion of domestic uranium mining, government actions that would enhance this could include:

o Resolve Plutonium Recycle. Resolution of plutonium recycle licensing questions would be needed within 1974.

o Resolve Imports of Uranium. Resolution of the import issue would be needed at an early date to provide the basis for large new investments in exploration, mine development, and mill construction by the mining companies and to instill confidence in their customers that adequate uranium supplies will be available.

o Make Government Lands Available. Many attractive uranium exploration and production areas are on public lands; and access to these under appropriate conditions, including restoration, could be important in expanding the uranium resource base.

o Encourage Long-Term Uranium Contracts. Electric utility customers for uranium fuel could be encouraged to enter into long-term contracts for their requirements to a greater extent than being done today. One way to do this is to require that a utility shall have committed itself to purchase fuel for some reasonable period of time as a condition of receiving a construction permit.

o Maintain the Stockpile. The wisdom of "working off" the present stockpile of uranium, currently about 50, 000 tons, as a part of AEC contract-enrichment operations is questionable. Under conditions of potential future uranium shortfalls, it would seem prudent to maintain this as a reserve, which could give added incentive to the uranium mining industry in the near future.

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[*] At least one member of the Task Force feels that the success of uranium exploration efforts may be the limiting factor in achieving nuclear power goals.

Uranium Enrichment

The enrichment of uranium from the 0.71 percent natural U^{235} content to the roughly 3 percent needed in light-water reactors requires large and expensive facilities that, if based on the diffusion process used to date, also require large amounts of electric power. The investments required and the amounts of power needed are very large for each single project, requiring on the order of $2 billion each and power supplies of about 2,500 Mwe for a 9 million SWU* per year gaseous diffusion enrichment plant. The future requirements for uranium enrichment capacity depend on the growth rate of the domestic nuclear power industry and are also affected by plutonium recycle and the tailings concentration. A lower tailings concentration uses less uranium but requires more separative work.

Another important factor in predicting enrichment demand is that the United States has been contracting for and supplying substantial enrichment services overseas. However, plans are underway to build large enriching facilities in France, the United Kingdom, Holland, and perhaps in other countries; and the USSR is now offering enrichment services on a significant scale and at attractive prices.

The AEC is presently the sole supplier of enriched uranium within the United States and operates three enrichment plants with a present capacity of about 17 million SWU per year, which with new, improved equipment but no new power supplies is being expanded to about 23 million SWU per year by 1980. A further expansion called the Cascade Upgrading Program (CUP) to 28 million SWU per year is scheduled for completion in 1983 and will require additional power supplies of about 1,300 Mwe.[18] While a large part of the added power will be needed by 1980, the AEC does not have firm contracts for this power supply as yet. To the extent that power, uranium, and operating funds are available, the AEC is also engaged in a preproduction program to stockpile enriched uranium for future use.

This overall situation is extraordinarily complex and has been covered in Atomic Industrial Forum (AIF) reports and Joint Committee on Atomic Energy (JCAE) hearings at great length. While the AEC has recently maintained that new enrichment capacity might not be needed in the United States before 1984 or even 1985, the consensus of industry appears to be that prudent planning today must anticipate a large block of new enrichment capacity coming into operation in 1982 or 1983 at the latest, with additional large units added every 18 months or 2 years for many years thereafter.

With estimated lead times of 7 to 9 years for design and construction, it is clear that initiation of plant expansion by entirely new facilities must get underway very soon to alleviate the rising uncertainties in this critical area.

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*An SWU is a separative work unit, not a physical quantity. It defines the size of an enrichment plant.

It appears that industry would be able to provide these new facilities, but only if some substantial issues are resolved in addition to the uncertainties discussed above. Some of these issues are:

o The classified status of key enrichment technology, particularly that concerning new processes such as the gas centrifuge and the laser.

o The entry of private industry into the uranium enrichment market, which is presently monopolized by a government agency.

o A reluctance by electric utilities to consider long-term take-or-pay contracts, which arises from numerous uncertainties, including the lack of access to classified uranium enrichment technology; under such contracts the utilities would share the financial risks.

o While overseas contracts can be important in establishing financing for new domestic enrichment plants, there are problems for such major long-term purchasers/investors arising from the classification of information and limitations on any significant foreign participation that might constitute what the 1954 Atomic Energy Act (Section 104, Paragraph D) refers to as "control" without further definition.

o The difficulties in achieving a 1982 or 1983 startup are many in the face of late resolution of these broad issues; 9- to 10-year lead times for new nuclear power supplies, 6- to 7-year lead times for new coal-fired power supplies, which might not be controlling; and access to classified data granted less than 1 year ago to companies interested in building enrichment plants.

Nevertheless, the Task Force believes that U.S. industry can build the new enriching capacity by the time that it is needed, using either the diffusion process or the centrifuge process or perhaps a mixture of both. There are, however, a number of actions that could be taken by the government to enhance the achievement of this end. These would include the following:

o Reduce Classification. Enrichment data could be downgraded and declassified, perhaps converting most to a "proprietary" classification and making it available to qualified companies under proper safeguards.

o Resolve Supplies of Power. Resolution of uncertainties with respect to the power supplies for the CUP would be needed since this block of capacity represents a significant difference in the time new additional capacity is required.

o Resolve Plutonium Recycle. Resolution of the plutonium recycle question would be needed, since an inability to utilize recovered plutonium would advance by 15 months the date by which new enrichment capacity would be needed.[15]

o Early Resolutions of Mining Questions. Uranium availability and separative work demand are inversely related. A shortfall of uranium would increase separative work capacity requirements substantially and vice versa.

o Utilization of Government Enriching Capacity. Resolution of ownership questions relating to existing AEC plants and to marketing in competition with new industrial plants would be needed. The AEC proposes to sell out its capacity first and then leave the market to industry. If it was to stop contracting earlier, it would greatly facilitate the entry of industry, and the uncontracted capacity could provide a contingency supply capacity.

o Resolve Foreign Involvement. The allowable role of foreign purchasers should be better defined, since they will be supporting plant financing through long-term contracts; and some may wish not only to have inputs to pertinent data but also into the management of companies with whom they have major contracts.

o Allow Access to Foreign Process Data. Domestic companies should have access not only to U.S. enrichment data but also to foreign data through AEC and/or industrial agreements so that they will have an adequate basis for business decisions, including data on all potentially competitive processes. This is now inhibited by AEC regulations (10 CFR, Part 25) even on an unclassified basis.

Waste Disposal

The management of radioactive wastes, including storage and disposal, does not appear to be a serious constraint on the growth of the industry. While radioactive wastes are hazardous and must be stored for long periods of time, large amounts have been handled safely for long periods; and new storage methods are being developed that should improve on the past record.

Long-term (100-year) interim and retrievable storage now being developed by the AEC will permit storing wastes produced through the year 2000 on a desert tract of 100 to 2,300 acres, depending on the concept selected, and at a cost of less than 0.5 percent of the cost of producing the related power.[19] Permanent disposal in geologic formations appears feasible and attractive but still needs adequate demonstration. Providing the basic facts and information to the public in an understandable and credible form should do much to alleviate unwarranted concerns over this matter. Similarly, the safety of transport of irradiated nuclear fuel has been very high, and the conditions are even better for radioactive wastes that are allowed to cool for several years and then converted to solid form. Again, the action needed appears to be that of communicating this to the public in an understandable form.

Safeguards

One area of increasing public concern, and one that involves some thoughtful trade-offs, is that of "safeguards." This is the problem of preventing the theft of fissionable or highly radioactive material for the purpose of making a bomb or for other nefarious purposes. The problem is primarily associated with reprocessing facilities and those fuel fabrication facilities using highly enriched uranium or plutonium. Fuel in power plants is of low enrichment, clad in zirconium, and usually in large heavy assemblies, and not of the type that might be attractive. Irradiated fuel is highly radioactive as well as being in heavy, countable, discrete pieces shipped in containers weighing many tons.

Much thought has been given to this problem and many procedures devised for improving safeguards or detecting losses and diversions. However, the simple fact remains that even a level of safeguards so expensive that nuclear power would be precluded still could not absolutely guarantee that some diversion could not occur. Thus, society must make a difficult choice -- forego nuclear power or accept a small but real risk. The question is international in scope and applies to breeder and probably fusion reactors as well.

RENEWABLE RESOURCES

There is currently about 54 Gwe of installed hydroelectric power generating capacity in the United States.[20] Development of some additional hydroelectric sites that previously have been marginal will undoubtedly be done, and the 1985 installed capacity could reach 75 Gwe. This total probable increase is insignificant in the overall program necessary to satisfy the Nation's new energy requirements.

It is likely that watershed development will occur for a different reason, namely, to supply necessary water for coal-based synthetic fuels production, for slurry pipelines, for surface coal mine restoration, and for shale oil production and restoration. Water consumed in such activities cannot be used for hydroelectric purposes.

There are other renewable resources, however. Geothermal power has been exploited for a long time, but it has never made a large contribution to the total energy supply. There are many small installations around the world -- in New Zealand, Italy, California, and elsewhere. All of these are near-surface installations associated with very limited volcanic areas or heat risers in the earth's crust. The steam is formed by natural groundwaters and usually is laden with a variety of corrosive materials such as sulfur and salts.

Another type of geothermal power is the so-called "dry-rock" type, where waters from the surface are injected to contact hot rock in deep wells to form steam. This latter type of geothermal energy is being suggested as a potential major source of electric power and heat. The development of this technology to levels of significance before 1985 is difficult to envision.

This is not to say that development of geothermal energy should not proceed. The Task Force believes that a logical, orderly program should be carried out in those areas where geothermal power is practical and economical. Some have suggested a 1985 goal of perhaps 7 Gwe.[10] This would be a very large expansion over the installed geothermal capacity today, and it is difficult to see it being accomplished. However, even if done, it would be extremely small in relation to the Nation's power needs, being the equivalent of about 0.2 MBPD.

OIL- AND GAS-FIRED STATIONS

There are many oil- and gas-fired units in base-load operation in some areas of the Nation. While it might be desirable to decrease natural gas use for this purpose, oil-fired units must be utilized for many years to come, particularly in cycling and peaking service. However, the lower the load factor, the less fuel these plants consume. The function of oil- and gas-fired plants in the future probably should be to provide cycling and peaking capability, not base-load energy.

It is not practical to convert existing oil- and gas-fired units to coal, since they have no provisions for coal storage, coal and ash handling, precipitators, or SO_2 removal equipment. Furthermore, the furnaces are too small for handling pulverized coal, and the plants would have to be derated.

Gas-fired units could possibly be converted to burn medium-Btu gas from coal, as discussed previously. However, the cost of manufacturing and transporting such gas is economically unattractive compared with natural gas, if such gas is reasonably available. The alternative is to relegate natural-gas-fired units more and more only to providing peaking capacity.

It therefore remains for nuclear and coal-fired units to supply the bulk of new base-load power. Economic forces will increasingly divert available liquid and gas energy sources to markets where they do not compete with low-cost nuclear and coal-fired electricity. However, SO_2 regulations might continue to hamper the transition to coal.

OIL- AND GAS-FIRED PLANTS

Type	1973[a] Gwe	1974-1985 Additions, Gwe	1985 Gwe
Conversions from coal	30	-20	10
Oil/gas-fired steam	145	-25	120
Gas turbines & internal combustion	38	+12	50
Total	213	-33	180

[a] Estimated from References 11 and 20.

As can be implied from the table above, the Task Force believes that reconversions to coal probably will occur and that about 50 Gwe of natural-gas-firing capacity could be diverted to oil- or coal-based medium-Btu gas.

TRANSMISSION

Generation of electrical power requires a concurrent capability for delivery to consuming markets, which are predominantly concentrated in urban centers. In the current proven state of the art, power transmission is accomplished over maximum main transmission lines at voltages up to 765 kv. Because of system instabilities, difficulties are often encountered at long distances. While 1,100-kv systems for higher flows have been developed, no major network yet exists using such voltages. A 500-kv dc technology now exists that is capable of transmission for long distances well beyond 700 miles. Ac-dc conversion costs are great but will decrease as solid-state technology improves.

The principal problems that face the transmission industry are system stability, corona discharges, and obtaining rights-of-way for overhead lines. There is also a growing problem in the divergence of the summer and winter system peaks, particularly in Federal Power Commission (FPC) Regions 4 and 5. If this divergence continues unabated, excess generation, transmission, and distribution facilities will have to be installed solely to meet the summer air conditioning peak; and either electricity costs in general will rise because of the unused capacity at other times, or the true costs of summer air conditioning will have to be recognized.

The Task Force concluded that the following government actions could be instrumental in meeting transmission needs:

o Help utilities secure adequate rights-of-way for transmission lines.

o Encourage stronger nonsynchronous interties between contiguous systems to achieve stability and diversity.

STORAGE

Since high-voltage, alternating-current electricity cannot be stored it must be converted to other forms before storage. Present schemes take several forms, including water storage, compressed air storage, and batteries. Briefly, the two major mechanical schemes absorb excess electricity during off-peak hours by pumping working fluids to a higher energy state (elevation, pressure) and returning electrical energy to the grid during peak demand hours, usually morning and evening.

Pumped-storage schemes are energy absorbers and capacity producers. Therefore, while they fulfill a vital function to base-loaded units on the system, they are in fact energy-consuming units. For this reason, they are important and valuable adjuncts principally to coal-fired and nuclear-generating units. About 45 Gwe of pumped storage units could be expected by 1985.

If the estimated nuclear and coal-fired power plant programs described earlier are achieved, a total of about 500 Gwe of essentially base-loaded capacity will be installed out of a total of roughly 1,000 Gwe in 1985. Unless something dramatic occurs in consumer demand to improve overall load factors, this base-load capacity would be too much. Hence, of the total 330 Gwe of coal-fired capacity, about 130 Gwe is expected to be relegated to cyclic load. In addition, about 45 Gwe of pumped-storage units could be used plus perhaps another 50 Gwe cycling capability from the nuclear plants that came on-line in the 1970 to 1975 period. Since there is about 8 Gwe of pumped-storage capability today,[20] this estimate represents the addition of an average of 18 new 200-Mwe pumped-storage systems every year for 10 years.

OVERALL GENERATING CAPACITY (Gwe)

	1973	1985
Nuclear	21	325[a]
Coal (solids)	143[b]	330
Oil/gas	175[b]	130
Gas turbine & internal combustion	38	50
Medium-Btu syngas	--	20
Hydro	54	75
Geothermal	Nil	7
Pumped storage	8	45
Total	439	982

[a] At end of year; average for year, 250 Gwe.

[b] Estimated split. Total fossil-fired steam was 318 Gwe.[20]

WATER

Thermal power plants require substantial amounts of water for cooling purposes. While there are environmental effects from warming the cooling water, the principal one is the evaporation of about 5 lb of water for each Kwh produced. This consumption is about the same whether the cooling is once-through, cooling towers, ponds, etc. It would not, of course, apply for air cooling. The power production considered feasible in 1985 would result in the consumption of about 7 million acre-feet per year of water or about 27 gallons per day per person. This compares with overall freshwater consumption for 1970 estimated at 98 million acre-feet per year or 425 gallons per day per person.[21]

The demands on freshwater supplies can be reduced by use of seawater for power plants located in coastal areas. Various coastal protection measures in many states are, however, making such siting and use of seawater almost impossible.

The use of cooling towers reduces the efficiency of power plants, which not only increases their cost per unit of capacity but also increases the amount of fuel required to produce a given amount of power. Air cooling has been used in various areas on relatively small plants and might become used more widely in the United States, although costs are high and the impact on fuel consumption is also high due to the large reduction in plant efficiency.

Typical effects on efficiency and fuel use are about 1-3 percent for wet cooling towers and 10-15 percent for air cooling, as compared with once-through water cooling.

As the efficiency of water cooled power plants decreases, the amount of water consumed (evaporated) is increased since more reject heat must be disposed of. For example, a reduction in efficiency of a nuclear plant from 32-30 percent would increase the amount of cooling water needed by 10 percent.

Chapter 6

SHALE OIL

INTRODUCTION AND OVERVIEW

The large oil-bearing shale deposits in the Green River formation of Colorado, Wyoming, and Utah have been estimated to contain some 1,800 billion barrels of oil -- more than four times the crude oil in place discovered to date in the United States. However, only about 6 percent of the deposits are accessible and are in seams 30 or more feet thick containing more than 30 gallons of oil per ton of rock. Only such very rich deposits and outcroppings are of current commercial interest in the $6 to $8 per bbl price range.[10]

Recovery of oil from shale is a very old art that has never been carried out on a large commercial scale in the United States. In work performed by industry and the Bureau of Mines over the past several years, shale-oil mining technology for the richer seams has been developed; and mining costs are reasonably well established. Environmental restoration costs may not be so well established.

Recovery of shale oil (kerogen) from the rock in which it occurs and conversion to a synthetic crude low in nitrogen and suitable for transportation as a liquid have been demonstrated in pilot plants. From the results of these pilot plants and based on announced industrial plans, the Task Force judged that surface retorting processes probably have reached a point where commercial scale-up can begin. Surface retorting means mining the oil-bearing rock, bringing it to the surface, retorting it to extract the oil, and disposing of the spent shale. Mining of shale for commercial purposes must necessarily be on a huge scale. Even the achievement of 1 MBPD of syncrude, while not large in terms of the overall demand of oil and total energy, would require the mining of rock at the rate of over 500 MTPY. This is almost equal in tonnage to the entire 1973 production of the whole U.S. coal mining industry, although not in volume because of greater rock density. Shale must be handled twice, further compounding the problem. The excavation and disposal of such quantities of rock present technical and environmental problems of great magnitude.

The tailings from even one 0.1-MBPD plant will accumulate at the rate of 40 to 50 acre-feet per day. Since the volume of the retorted tailings is considerably greater than that of the mined rock, little more than half of this can be returned to the mine. While there is space for such tailings in remote canyons near the deposits, rainfall leaching could affect the quality of water runoff in rivers downslope unless preventive measures are taken or restoration is done. Because no great amount of spent shale has yet been accumulated, the total range of problems, including replanting, stabilizing, and leaching, is not well defined. This issue is of such importance that continued lack of answers could delay or jeopardize the early availability of oil from these domestic resources.

Recently, preliminary studies have been conducted on in situ retorting of shale, that is, extracting the oil underground. Only a much smaller quantity of rock is mined and brought to the surface to create a cavity. This work may prove attractive but has not yet progressed to a point where it is possible to pass judgment on its feasibility. The Task Force believes that to delay construction of commercial size above-ground retorting plants on the basis of such speculative alternative prospects would serve only to eliminate shale oil from any beneficial contribution in the pre-1985 period.

A major problem associated with shale oil development is water availability. While some major studies by others have assumed that excess water was available in the Colorado River watershed, the Task Force understands that such water may already be overcommitted for other uses and that supply is not likely to improve. Undoubtedly, some agricultural water rights can be purchased, but these would probably be only a small fraction of the needs of a significant commercial shale oil industry. Indeed, the Task Force believes that one ultimate limitation on shale oil production will be water availability, unless major amounts of water are brought in from elsewhere.

The size and location of tracts currently available to private operators is also a problem. About 80 percent of all shale reserves lie within federal lands, and the government currently restricts leaseholdings to about 5,000 acres. Such tracts are too small to give assurance of an adequate 20-30-year supply of shale, and many tracts have reserves inadequate to support even a single commercial plant. Development conditions requiring many companies to build their own prototype plants are inefficient and wasteful. The size of contiguous tracts needs to be tripled or even quadrupled to provide reasonable incentives for efficient commercial development.

ESTIMATED PRODUCTION CAPABILITY

Two new industrial semicommercial plants have already been announced to be on-line by 1979, and considerable interest has attended the recent

Colorado lease sales, as the bids in the hundreds of millions of dollars will attest. Utah and Wyoming tracts are being leased. Despite this activity, the lead times and the serious problems facing the industry force the Task Force to conclude that the maximum target production rate by 1985 cannot realistically exceed 0.5 MBPD. Even this target is an extremely large undertaking, involving the capital expenditure of some $3 billion to $5 billion in a new and unfamiliar technology.

Expressed in physical terms, this development could mean:

- Bringing into production 50 new 5-MTPY shale mines and retorting plants.
- Laying, stabilizing, and restoring 5 square miles of tailings 40 feet deep each year.
- Constructing 10 new 50,000-BPD upgrading plants and production pipelines.
- Developing and conveying 80,000 acre-feet per year to new water supplies in a water-scarce area.

The problems involving scale-up of the solids handling system for such unfamiliar material defy reasonable forecasting and suggest that pioneer plants be built soon for experience. A program of this magnitude, however, would mean that, on the average, five major shale mines would need to come into production every year for 10 years.

POSSIBLE GOVERNMENT ACTIONS

If it is desired to establish a viable major shale oil industry, it could be enhanced by the following government actions:

- Develop Acceptable Tailings Disposal Methods. The government could sponsor intensive studies regarding the environmental problems of large tailing heaps and sponsor field tests dealing with efficient rapid restoration methods and leach prevention.
- Make Federal Lands Available. Larger tracts of perhaps 15,000 contiguous acres each could be made available for leasing to provide incentives to industry.
- Determine Water Availability. The Bureau of Reclamation could sponsor water availability studies, including alternatives for developing new sources of water needed for shale oil production and restoration. The bureau could assist firms in obtaining allocations and rights to such water.

Chapter 7

OIL AND GAS

INTRODUCTION AND OVERVIEW

In the first 40 years of the 20th century, the United States gradually turned from coal to oil and gas as its primary energy sources. In the period of economic growth following World War II, the surge in private automobiles, the growth of diesel truck and airline traffic, the conversion of the railroads from coal to diesel power, and the rapid growth in oil- and gas-fired electrical generating capacity all contributed to a decline in coal production and an acceleration in growth of oil and gas consumption. The dominant position of oil and gas in today's economy is illustrated in the following table:

1973 U.S. ENERGY DEMAND (INCLUDES EXPORTS)[2]

Fuel/Resource	MBPD Oil Equiv.
Nuclear and hydro	1.8
Coal and lignite	6.8
Oil and gas	28.6
Total	37.2

These facts are important because they reflect the extent to which the U.S. consuming markets have embraced oil and gas in installed facilities.

1973 OIL AND GAS DEMANDS[2, 22, 23]

Fuel	Resource	Flows (MBPD)	Total (MBPD)
Petroleum liquids	Lands	8.3	13.2
	Continental shelves	1.8	
	Imports	3.1	
Oil products	Imports	3.0	3.0
Natural gas	Lands	9.4	12.4
	Continental shelves	2.5	
	Imports	0.5	
	Total	28.6	28.6

Imports

Until recently, most of the oil and gas used in the United States came from domestic sources, with small but significant imports from the rest of the Western Hemisphere. However, the combination of a leveling in domestic production and a burgeoning demand led to a rapid increase in imports in the last few years, largely from the Middle East.

A variety of estimates have been made of future import requirements, and most of these indicate that unless substantial additional effort is put into development of domestic sources, imports will grow to 10 MBPD and beyond within a few years. This oil will almost certainly come from the Middle East, where the world's spare capacity, whatever it may be, is likely to be concentrated. The Task Force believes that the United States has the resources and the technology to reverse this importation trend and to reduce imports by 1985 to a practical minimum that will be consistent with national policy if it is desired to do so. It is believed that such a practical minimum would include some imports for the foreseeable future for reasons of economics, world trade, and resource conservation.

Oil Storage

Storage of several months supply of either imported or domestic crude has been advocated to minimize problems caused by interruption of imports. It has been advocated that existing fields be taken off production to serve as emergency sources of oil. However, production from oil fields is limited by the percolation of the oil from the surrounding matrix and cannot exceed a fraction of 1 percent of the total volume per month, a slow rate set by nature; and, hence, shut-in oil fields cannot make a substantial impact in replacing imports for short-term emergencies.

It is true that oil can be extracted and then stored in salt domes and in tanks in sufficient quantities so that it could be withdrawn at a fast enough rate to meet temporary shortages. In Europe, storage of several months' supply of crude oil and oil products is commonly required. However, such storage is very expensive and inevitably increases the cost of products sold to the consumer.

While some increase in the amount of nationwide oil storage could be achieved and may be desirable, realistically it is not a long-term solution. Exporting countries, which can afford to forego revenues from the United States because of the demands from other nations, could withhold products from the United States for years.

Reserves

Crude reserves are defined as oil that is reasonably certain of being produced in the future from established reservoirs based on geological and engineering data under existing economic and operating conditions. Domestic reservoirs of oil discovered to date originally contained approximately 430 billion barrels of crude oil, but only about 140 billion barrels were classified as recoverable by conventional methods.[24] Of this amount, about 100 billion barrels have been produced, leaving approximately 40 billion barrels as current reserves. The principal existing reserves in the United States are found in the major basins of East and West Texas, the Los Angeles area of California, the Gulf Coast of Louisiana, and the North Slope of Alaska.

Additional substantial amounts of oil will undoubtedly be discovered in areas where considerable drilling has already taken place, particularly with improved price incentives for exploratory ventures. However, it is believed that most of the major fields in mature exploration areas have already been found and that additional fields will be smaller in size and more difficult to discover.

For this reason, increased attention has been focused on new areas or sediments that have not been yet explored. Some of these are deep formations that have heretofore been too expensive or difficult to drill, such as the very deep gas-bearing formations in Oklahoma. Others are those whose geological potential and underground configuration have not been well understood, such as the Jurassic trend in Alabama and the panhandle of Florida. But by far the most interesting, and believed to be highly prospective, are the Alaskan North Slope and the offshore areas of the East Coast and the Gulf of Alaska. The offshore areas in particular are known to have large volumes of sediments of the type which are normally conducive to the formation and retention of hydrocarbons. The actual existence of petroleum reserves in these sediments can only be proved by drilling operations, and the presence or absence of these reserves will be crucial in any efforts to increase domestic production by 1985.

Production Rate

Production rates are controlled by state regulatory agencies. In the past, production was prorated to match supply and demand, with no significant price movement. In the face of rising demand and limited domestic supplies, production rates were raised to the Maximum Efficient Rate (MER). The MER depends on a number of factors, such as reservoir size and quality, well spacing and depth, and oil characteristics; but the basic objective is to permit the field to be produced as rapidly and fairly as possible without damaging the reservoir and reducing its ultimate yield.

The question of possible reservoir damage at high production rates is a difficult one because of problems in scaling laboratory models to field conditions. Similarly, field tests are not favored, because, if damage is done, it is often irreparable. As a result, state agencies tend to be on the conservative side in setting MERs, and it is possible that some fields could be produced faster without appreciable reservoir damage. This will add to current production but, of course, will not add to ultimate reserves and is therefore not a long-term solution.

Declines in Production

A typical petroleum well or field exhibits high production in the initial few years followed by progressively declining production during the remainder of its life, which is usually on the order of a very few decades. The relatively rapid decline is due to a number of natural forces, some of which can be partially alleviated.

Eventually, however, physical diminution in the amount of oil and gas left, plus changes in the relative permeability of the formation to oil or gas caused by fluid migration, reduce the amount of petroleum that can be produced. At some point, the cost to operate a well and maintain its production facilities will approximate the value of the liquids or gas produced. So-called "stripper" wells are extraordinarily sensitive to economic conditions and improvements in technology. Profits from such production are usually low because of high producing costs. Yet these wells produce truly incremental domestic oil as opposed to simple acceleration of production. It is for this reason that separate regulations and economic incentives are sometimes applied to stripper production. Such wells can seldom be restored to economic production after they have been permanently shut down, and regulatory agencies tend to extend favorable treatment to them.

Most predictions for total U.S. domestic production in 1985 forecast that even with vigorous efforts and enhanced recovery the decline of oil and gas production from existing producing fields will be more than 50 percent below current levels. Most increases in production must come from new fields not yet developed.

Secondary and Tertiary Recovery

Reinjection of water or gas in order to arrest the normal decline in subsurface pressure is commonly done, and such procedures are referred to as "secondary recovery." These methods slow the decline in production, minimize wasteful bypassing of pockets of oil and gas, improve the economics, and hence promote greater ultimate production.

More advanced methods of recovery, called "tertiary recovery," have been under development for some years in the laboratory; and these have been studied in the field in a limited number of small tests. The most promising techniques include steam, in situ combustion, carbon dioxide, miscible flooding agents, and surfactants. Individual oil fields will demand specially tailored methods that are compatible with the unique characteristics of the formation and its contained fluids. These advanced methods can undoubtedly be developed during the next decade.

There are a number of difficulties that must be overcome, however. One is the fact that a large number of royalty owners and operators must be treated equitably, and agreements for unitization of fields for the benefit of all are difficult to formulate.

A more serious problem is the development and demonstration of improved tertiary recovery technology. Substantial scale-up of laboratory techniques is needed in a number of large field tests to give assurance that the technology is understood before widespread commercial application is undertaken. The payoff would be the ability to extract more of the approximately 290 billion barrels of oil remaining in the ground where 500,000 wells and their collecting lines already exist.

Uneconomic Fields

A large number of hydrocarbon-bearing formations are known that are currently uneconomic to produce. Principal reasons involve one or a combination of the following: The formations are too low in permeability, the productive strata are too thin, the value of fluids ultimately recovered from a given well does not exceed the cost of the well, and the production of unwanted fluids such as water make the producing operation too expensive.

Of particular interest are some known sands that are impermeable but are also extensive and contain hundreds of trillion cubic feet of gas. At present, the revenues from a well drilled to such formations often do not exceed the cost to drill and stimulate production to a high level, much less yield an acceptable return on investments. However, possible significant improvements in technology and economic incentives offer the prospect of substantial increases in domestic gas production under the proper circumstances.

Shut-In or Underproduced Fields

There are a number of very large oil fields currently not producing that could add substantially to the current U.S. supply. Elk Hills, a naval petroleum reserve located in California, has wells and production facilities already installed but not operating. Prudhoe Bay in Alaska and the offshore Santa Ynez field in California are two major reserves whose production has been delayed by environmental concerns.

A number of major fields now producing at maximum allowable rates could physically produce more if the MERs were raised. East Texas and Yates are the two most prominent.

Leasing of Government Lands

Discovery and exploration of new oil and gas fields depend on tract availability so that drilling can occur. Since the lead times for exploring and developing span many years, major tracts need to be opened for exploration soon if there is to be significant production before 1985. Except for the North Slope of Alaska, these major areas are almost exclusively found offshore.

While some "high-grading" has been achieved by the federal system of soliciting nominations for tracts offered in the past, the nominating areas within the tracts are limited. Recently, another procedure was proposed to rank unleased acreage by order of probable production potential and to offer the highest potential areas for lease first. Men, materials, and drilling rigs all are in limited supply and could be concentrated in areas having the highest probability of success by this change.

Related Facilities and Equipment

Acceleration of production from offshore areas is possible only if adequate equipment in sufficient quantity is available. A key item is the very limited number of ocean-going drill rigs capable of drilling in more than 150 feet of water. Lead time for construction of such rigs is fairly long, and their availability could be one of the limiting factors in accelerating offshore production. Clear signals will have to be given if drilling companies are to invest in this equipment prior to actual granting of offshore leases.

Refineries are normal and essential parts of the process of delivering petroleum energy to the consumer. Adequate domestic refining capacity existed for decades until just recently, when the certain decline in domestic production and the uncertain prospects of being able to import sufficient crude under existing government regulations led refiners to delay expansions and new constructions. The delay was also abetted in some cases by environmental concerns. The Task Force believes that these environmental concerns can be overcome with careful planning and that the economic incentives are such that, in the absence of suppressive government policies, adequate refining capacity can and will be built to handle any increases in domestic production of oil.

Pipelines are recognized as an inexpensive, efficient, and potentially environmentally sound method of moving both liquid and gaseous hydrocarbons. However, the trans-Alaska pipeline has already been delayed considerably; a gas pipeline from Alaska will undoubtedly receive careful scrutiny, and new pipelines will have to demonstrate that they are environmentally safe as well as economically viable. With careful attention to such matters, pipelines should continue to be useful movers of petroleum energy and should be available with the capacity sufficient to handle any anticipated increases in domestic production.

PRODUCTION PROGRAMS

Declines in Production from Existing Fields

The normal decline in production rate from oil and gas fields is known with reasonable accuracy. Existing fields, which in 1973 produced 10.1 MBPD of oil and 67 BCFD of gas, are expected to decline by 6 MBPD of oil and 39.4 BCFD of gas by 1985. The production rate decrease would be much greater but for the expected application of secondary recovery operations, which will account for well over half of production from known fields in 1985. Tertiary recovery from existing fields is normally expected to amount to about 0.5 MBPD by the end of the next decade.

Production from New Fields

New fields will continue to be found and brought into production as an ordinary and usual part of the petroleum industry's operations in the years ahead. Increases in production are necessarily incremental and slow in developing because of the nature of the drilling and producing operation; immediate results from a changed economic or regulatory climate cannot be expected. The cumulative impact over a decade is substantial, however. Based on reasonable assumptions about the future, the Task Force estimates that production from new fields will amount to 5.5 MBPD of oil and 36.6 BCFD of gas, not quite offsetting declines from known fields.

The assumptions on which these forecasts rest basically involve continuation of recent trends. For example, the price of domestic oil is assumed to be near but somewhat below its free market level in much of the next decade, with price controls or other restrictions in at least the initial years. The price of gas is assumed to rise substantially but not to reach parity on energy content with coal or oil because of extended price controls. Continued environmental pressures are visualized, but long delays on major projects such as that experienced by the trans-Alaska pipeline are not anticipated. Specifically, by 1985 the North Slope of Alaska is assumed to produce 2 MBPD of oil and 3 BCFD of gas. An accelerated leasing program for offshore government land is assumed, but not in the amounts or sequence that will maximize 1985 production. No technological breakthroughs are expected in drilling costs or tertiary recovery efficiency, and it is taken for granted that discoveries of new reserves per foot of hole drilled in mature exploration areas will continue their downward trends.

Accelerated Production and Leasing

One key to accelerating production of oil using known technology is the establishment of a better economic climate that leads the producer to expect to recover higher costs caused by taking greater risks or operating in a more expensive manner or area. The anticipated production increases described in the preceding section are based on an assumed improved economic climate. If domestic oil and gas were to closely approach price parity with imported crude, the incentives would stimulate industry to accelerate production efforts, and substantial production increases could be achieved by 1985.

In such an economic climate, increased cash flow and improved prospects for profitable discoveries would cause exploration efforts to be substantially expanded. The drilling of outpost and development wells in mature producing areas would be strongly stimulated.

Wells that were not drilled because of marginal economics would be attractive with higher oil and gas prices to offset higher drilling and operating costs. Production from known but presently noncommercial reservoirs (e.g., tight or thin formations) would become feasible. Workover of wells to increase rates of production would be stimulated, although this would not change reserves or eventual production. However, it would accelerate production in the decade ahead. Abandonment of stripper wells would be delayed as a result of reducing the lowest rate at which production is economically feasible. Also, more secondary recovery projects would be initiated, thereby increasing recoverable reserves and accelerating production.

The number of individual investment opportunities, investment criteria, and investment decision-makers that will determine actual responses with price increases is so large and poorly defined that confident prediction is most difficult. All who have studied the relationship agree that increased economic incentives would bring forth additional supply over a sufficiently long period of time, although there is less agreement concerning the exact level. Further, the use of economic incentives to stimulate the above activities appears to be by far the most effective method.

A second key step in accelerating production is to make available more federal acreage in areas having the highest geological potential. There are in the United States a number of highly promising petroleum provinces that have not been definitively explored because of their unavailability. If these areas are to make a contribution to the petroleum supply by 1985, action must be taken soon. In hostile offshore environments, the time from granting of a lease to the first significant production may be on the order of 7 to 10 years. Even in areas close to established supply bases, development of production may require 2 to 3 years after a lease is granted. Of course, extensive geological and geophysical work is required before leasing. If increased domestic oil and gas production is desired, the new areas should be made available for industry leasing as soon as possible, with the prospective tracts having the highest potential being offered first.

With these qualifications, and assuming adequate incentives supplied by free operation of the energy market and available federal acreage, it is estimated that production could be increased an additional 2 MBPD of oil and another 14 BCFD (2.5 MBPD oil equivalent) of natural gas by 1985.

Additional Known Fields

Capable fields that are presently restricted could be brought into production. The Elk Hills field, for example, could almost immediately produce 0.16 MBPD of oil, if making this naval petroleum reserve available to meet the Nation's current energy needs is acceptable national policy. The original rationale for setting such reserves aside may no longer be germane. Other naval petroleum reserves, such as the NPR-4 on the North Slope of Alaska, could be sold or leased for production, if conditions warranted such a step. However, no forecast of possible production from these is included in this analysis.

There are a few large fields (e.g., Yates, East Texas) where production could be increased above present rates. Under the present regulatory system, changes cannot be made by the federal government; and no increases have been assumed for these fields.

Prudhoe Bay and Santa Ynez (Santa Barbara Channel) are two large fields where development has been delayed for environmental reasons. It is assumed that these two fields will be producing substantial amounts by 1980. Failure to bring them into production would substantially increase supply/demand problems or levels of imports required.

Tertiary Oil Recovery Methods

U.S. oil reservoirs discovered to date originally contained approximately 430 billion barrels of oil. Primary recovery operations and conventional water and gas injection secondary recovery operations have already recovered or will recover about 140 billion barrels from these reservoirs, leaving some 290 billion barrels that cannot be produced by conventional methods.[24]

Several processes have been under development for achieving higher recovery than is possible with conventional production methods. These enhanced recovery processes for the most part have not been economically attractive to date. They do offer potential for affording worthwhile volumes of additional oil production by the early 1980's if economic and technological problems can be resolved. Different processes appear most promising for certain types of fields. Additional laboratory work and a substantial number of large-scale field tests are needed to complete development of the technology. Different field tests should proceed simultaneously, not sequentially; companies developing the technology should be permitted to cooperate, free of antitrust restraints.

If a program of government assisted field tests is undertaken to overcome obstacles and implement enhanced oil recovery applications, it appears possible that these applications may yield 0.5 MBPD by 1980 and 1.3 MBPD by 1985. These volumes represent increments of 0.2 MBPD in 1980 and 0.8 MBPD in 1985 over what can be expected without the program.

Gas Production from Low Permeability Sands

The National Gas Survey estimated that 600 TCF of gas was in place in tight sand reservoirs in the Green River, Piceance, and Uinta basins of the Rocky Mountain area,[25] and the Gulf University Research Consortium estimated that an additional 625 TCF was in place in tight sand reservoirs in other basins.[24] If 10 percent of the gas in place in tight sand reservoirs could be recovered at 10 billion cubic feet per well, 12,000 wells would be needed. At a conservative $2 million per well, the investment required is $24 billion.

Government assistance will be needed in achieving fair market gas values, completing development of nuclear and possibly hydraulic fracturing technology, overcoming environmental problems, and assuring availability of materials in order to accomplish large-scale development of the tight sand gas reservoirs by the early 1980's. If such an effort is made to develop the tight sand gas reservoirs, it is possible that production levels of 2 BCF per day by 1980 and 3 BCF per day by 1985 could be attained.

Total Production

A summary of the production that could be achievable by 1985 is shown below. The top two rows of incremental production figures represent the anticipated production under the assumptions described on page 80. The remaining portion of this table shows the incremental production, beyond 1973, which the Task Force judged to be realistically possible under the more favorable conditions outlined in this report.

1985 ESTIMATED POSSIBLE OIL/GAS PRODUCTION

Source	Gas BCFD	Gas MBPD Equiv.	Oil (MBPD)	Total (MBPD) Equiv.
1973 Production	67.0	11.9	10.1	22.0
Declines in 1973 fields	(39.4)	(7.0)	(6.0)	(13.0)
Production from new fields	36.6	6.5	5.5	12.0
Accelerated production and leasing	13.8	2.5	1.9	4.4
Additional known fields	0.1	--	0.2	0.2
Accelerated tertiary oil recovery methods	0.4	0.1	0.8	0.9
Gas production from low-permeability sands	3.0	0.5	--	0.5
Subtotal: Incremental production by 1985	14.5	2.6	2.4	5.0
Grand Total	81.5	14.5	12.5	27.0

The magnitude of such oil and gas expansion can be visualized by illustrating the activities associated with those expansion efforts:

OIL/GAS SUPPORTING ACTIVITIES

	1973	1985
Offshore employees[26]	49,000	165,000
Total employees (excluding refineries)[27]	265,000	330,000
Mobile offshore drilling rigs	50	180
Platform drilling rigs	40	570
Number of platforms in place	2,000	3,700
Tubular goods (MTPY)	1.5	2.8
Pipeline goods (MTPY)	1.9	2.4
Platform steel (MTPY)	0.3	1.9
Other steel (MTPY)	0.4	0.4
Total steel required (MTPY)[28, 29]	4.1	7.5
Wells drilled per year[30]	30,000	58,000
Average depth of well[30]	5,040	5,400

POSSIBLE GOVERNMENT ACTIONS

If it is desired to increase domestic oil and gas production, government actions that could enhance this include:

- o New leases. New leases could be made available offshore and on federal lands in quantities that industry can absorb and in order of geologic promise.
- o Known fields. Elk Hills and other naval petroleum reserves could be leased and production initiated.
- o Low-permeability gas reserves. The government could encourage evaluation of nuclear stimulation of tight gas sands by continuing to make explosives available and possibly sharing some of the demonstration costs. Hydrofracturing methods may also need assistance if private efforts falter.
- o Tertiary recovery techniques. The government could extend financial support to field testing of new techniques for recovering oil from depleted or nearly depleted fields.

Chapter 8

OVERALL CONSIDERATIONS

The previous chapters dealt with the decreases in demand and the increases in domestic energy production in individual energy areas that might realistically be brought about in the next 11 years. It has been assumed that despite the urgency, government and industry will operate in their traditional peacetime roles and that a wartime "crash" effort will not be necessary. In each area, estimates have been made of the magnitude of the energy production that might be achieved, along with identification of some of the problems, barriers, and possible solutions. The magnitude of each program was assessed, but no attempt was made to assess overall costs or feasibility in terms of a total program in which parallel effort would be underway in several or all of the areas at once. This chapter seeks to evaluate the overall impact of the various programs. Together, they represent all of the possible approaches for making significant changes in energy supply-demand before 1985.

The desirability of carrying out the total program is beyond the scope of this study. It involves questions of costs and benefits, not only from the economic but also from the societal and political points of view. However, the description of this total program sheds some light on the maximum effort that may be feasible by 1985. It provides further insight into some of the problems that will need to be resolved in arriving at a national energy policy.

It was necessary to limit the consideration to essentially one date (1985) in order to keep the scope of the study within the practical limits of the Task Force, and so this report should be considered an estimate of what could be accomplished by that time. It was not possible within this limited study to prepare detailed schedules of supply and demand throughout the decade.

PROJECTED DOMESTIC SUPPLIES

The following table summarizes the separate projections made in Chapters 4 to 7 of potential U.S. energy production in 1985. These projections were derived individually for each primary energy industry. They reflect the Task Force's judgment of what is reasonably possible with existing technical capabilities, existing natural resources, early access to new natural resources, removal of administrative and regulatory impediments, and efficient operation of the Nation's economic system by providing incentives to attain the desired end results.

The Task Force cautions that these separate projections represent an upper limit to what is believed reasonably attainable. They neither reflect production targets, nor do they imply necessarily a satisfactory mix of energy forms for supplying projected consumption demands. The Task Force acknowledges that more rapid expansions of some energy forms may be possible through "crash" programs but with attendant high costs, poor risks, and wasteful inefficiencies.

POTENTIAL 1985 U.S. ENERGY PRODUCTION (MBPD)

Resource	Energy Form	Production	Totals
Coal:	Coal solids	10.0	11.7
	Pipeline quality SNG	0.8	
	Methanol	0.3	
	Synthetic crude	0.3	
	Medium-Btu	0.3	
Nuclear:	Uranium-Plutonium	8.3	8.3
Renewable:	Hydroelectric	1.5	1.7
	Geothermal and all other	0.2	
Oil:	Crude oil— accelerated production and leasing	1.9	12.5
	Crude oil — additional known fields	0.2	
	Crude oil — accelerated tertiary recovery	0.8	
	Crude oil—decline in 1973 fields	(6.0)	
	Crude oil— production from new fields	5.5	
	Crude oil— 1973 production	11.8	

POTENTIAL 1985 U.S. ENERGY PRODUCTION (MBPD) — continued

Resource	Energy Form	Production	Totals
Shale:	Synthetic crude	0.5	0.5
Gas:	Natural gas—accelerated production and leasing	2.5	14.5
	Natural gas— low-permeability sands	0.6	
	Natural Gas— decline in 1973 fields	(7.0)	
	Natural gas— production from new fields	6.5	
	Natural gas— 1973 production	11.9	
		TOTAL	49.2

This total production would make available 10 MBPD of coal solids, 13.6 MBPD of petroleum liquids, and 15.6 MBPD of gases in addition to the electricity generated from nuclear, hydroelectric, and geothermal energy sources.

Orderly Expansion. The Task Force believes that its 1985 estimates could be achieved through an orderly transition to higher production levels. Inflationary impacts on the rest of the economy and disruptive relocations of capital and labor could be minimized by this approach.

Competitive Interactions. Simultaneous expansion of the various individual energy capacities would create competitive interactions that are not reflected in the table estimates. Shortages and bottlenecks might be created as different industries compete for limited supplies of labor, equipment, and materials. This competition might not be adverse; competition for supplies and materials could have beneficial and synergistic effects, resulting in improved capability for meeting demand.

PROJECTED ENERGY DEMAND

The following table summarizes the projected U.S. energy demand by 1985, drawing on the estimates made in Chapters 2 and 3. The historical demand projection represents a continuation of the patterns of energy use that occurred during the 1960's and reflects the former availability of cheap energy.

Future demand is expected to fall below this historical projection as a consequence of increased energy costs. The table expresses a projection of demand resulting from an assumed oil price in terms of 1974 dollars of $7 to $8 per barrel through 1985.

ESTIMATED 1985 ENERGY DEMAND (MBPD)

Previously projected demand (Chapter 2)	58
Less savings from conservation and improved efficiency (Chapter 3)	8-9
Net demand	49-50

As noted in Chapter 3, there are two basic categories of conservation measures. The first is the "do-with-less" type, which includes such voluntary and involuntary actions as reduced driving speeds, lower thermostat settings in winter, use of public transport in place of personal cars, and reduction of light bulb wattage. The second category of conservation involves some added capital investment and/or use of new technology by the consumer in view of the higher cost and reduced availability of certain energy forms. Conservation of this second type includes greater production of small automobiles; more efficient energy utilization in industry; more efficient space heating, air conditioning, and water heating in the residential and commercial sectors; and construction of more extensive mass transportation systems and greater use of car pools. To obtain more efficiency, more attention must be placed on the lifetime costs of industrial and consumer goods using energy.

The effects of the second category would be slow in coming, but once implemented they would be more or less permanent. On the other hand, the effects of the "do-with-less" category, while immediate, may not persist with time. At this point, the Task Force has little data on which to base conservation trends for either category. In all likelihood, the resulting effects from any of the above are dependent on both types of conservation and are strongly interrelated. Based on present events and best judgment, the Task Force believes a reduction of 8 to 9 MBPD might be achieved from all conservation measures by 1985.*

*One member of the Task Force believes that on the basis of studies performed at the Environmental Quality Laboratory of the California Institute of Technology, the reduction in demand could be as high as 12 MBPD by 1985.

BALANCE OF SUPPLY AND DEMAND

Task Force estimates of potential supply are compared with the estimate of demand as reduced by conservation in Figure 4. While a summation of the possible results from all of the programs discussed in previous chapters gives a total that would indicate the possibility of reducing imports to a low level by about 1985 or possibly eliminating them, such a conclusion must be viewed with caution and is likely to be misleading for the following reasons:

- o It is unlikely that all portions of all of the potential programs will be considered desirable in terms of cost, environmental effects, etc.
- o It is unlikely that all of those programs judged feasible and desirable would be started immediately (1974) as assumed.
- o It is unlikely that all of the programs initiated would be carried out successfully in terms of results, schedules, etc.
- o Some of the effects of the "conservation ethic" would probably disappear if the prospects for continuing adequate energy supplies improved.
- o The requirements for carrying out all of the potential programs simultaneously may place unacceptable strains on capital, manpower, water, materials, and the environment.

It must also be stressed that all of the estimates used have a very low degree of precision. This includes the postulated increase in demand, including likely reductions because of conservation incentives and increased prices, as well as the possible increases in supply for each of the types of energy covered.

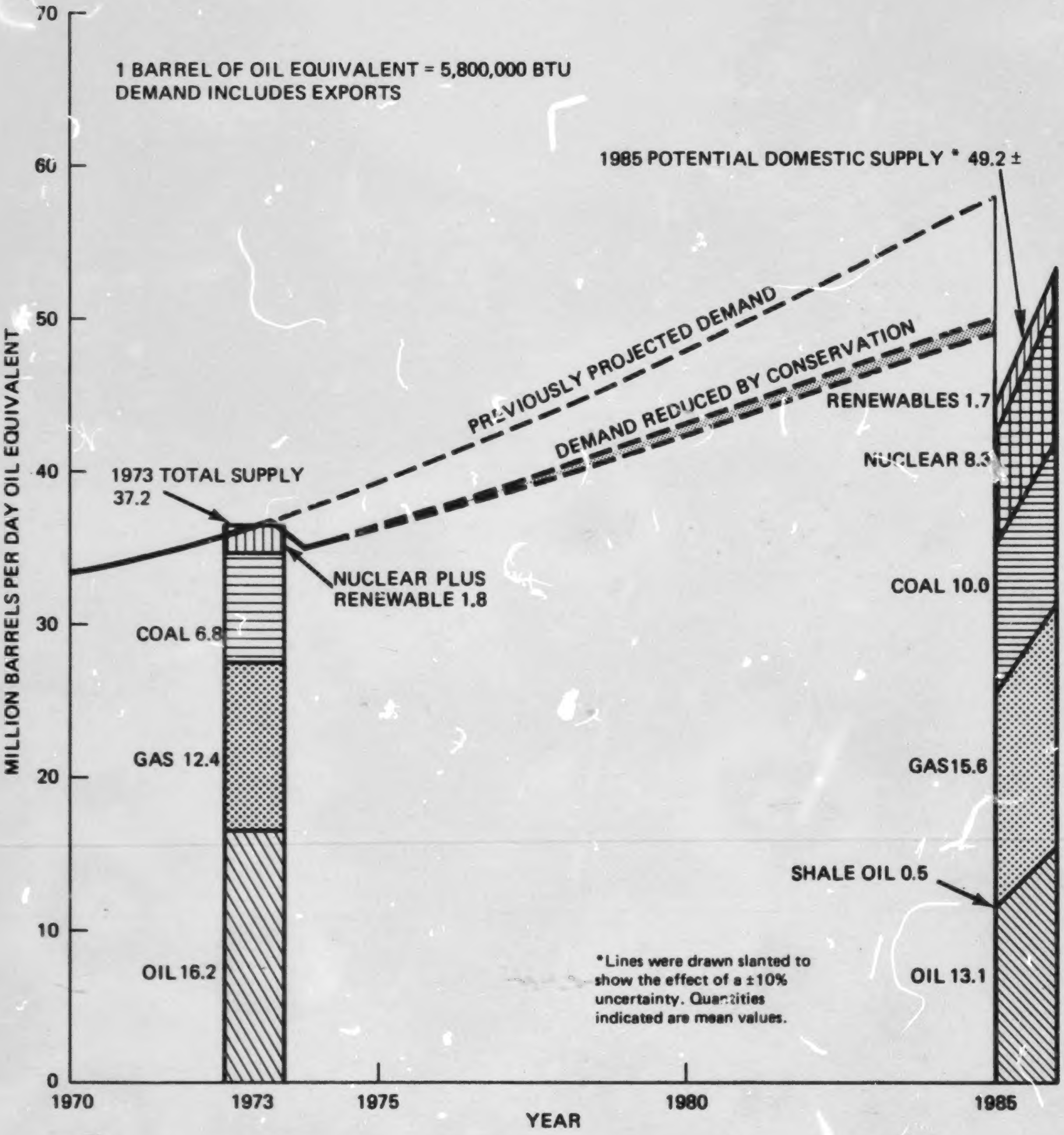
While no attempt has been made at any sort of mathematical analysis, it is felt that the total by 1985 may be no more accurate than ± 10 percent, and the individual items may be 15 percent in error by that time. Thus, it is clear that the estimates must be treated as "order of magnitude" at this stage.

Even if the programs could all be accomplished successfully and there was a surplus of energy produced in the United States, it might not be in the forms most suitable for use, which would require import of energy in some forms and provide an opportunity for coal exports.

These contingencies and imprecisions must certainly be taken into account in arriving at decisions as to what is a prudent program to be initiated in 1974.

A consideration of these potential rates of production by the end of 1985 reveals that the liquid hydrocarbon production, including shale, of

FIGURE 4 POSSIBLE U.S. ENERGY SUPPLY AND DEMAND



about 13.6 MBPD is significantly lower than the liquid hydrocarbon consumption in 1973, about 16.2 MBPD. Since the unrestrained preference for energy in the form of liquid fuels would surely increase over this period, the following points are significant:

o Imports of a few MBPD of oil will probably still be required in 1985 even if the programs outlined are pursued and are generally successful.

o Highest priority consideration should be given to those possible programs for reducing consumption of liquid hydrocarbons or switching present uses to other sources of energy, especially coal and nuclear energy. In particular, the programs deserving of maximum attention appear to be:

- Reduction of liquid fuel uses by autos, trucks, buses, and aircraft.
- Maximum use of coal and nuclear power production with minimum use of oil (or gas) in existing power generating stations.
- Conversion of industrial heating to coal instead of oil where feasible.

o Highest priority consideration should be given to possible programs for increasing the production of liquid fuels, with the following the most important:

- Increased exploration, development, and production of oil (and gas) from domestic resources.
- Use of oil shale to the extent possible in view of environmental and water constraints.
- Rapid development of coal liquefaction for possible large-scale use in the latter 1980's if necessary.

o To the extent that substitutions cannot be made for oil (and gas), and that either imports or additional domestic production are needed instead, the requirements for use of coal or nuclear power will be reduced. Thus 1 MBPD of oil from either source would reduce the requirements for coal by about 100 MTPY, or the required nuclear capacity by 36 Gwe.

Even if the liquid fuel demand could be balanced to match the domestic liquid fuel supply, some level of importation may well be desirable, if and when consistent with foreign policy and national security. Reasons for imports might include domestic resource conservation, world trade balance, and economics. From an economic viewpoint, it would seem desirable to keep domestic fuel prices from becoming too insulated from world market prices.

LEAD TIMES

One of the most difficult problems that must be faced in such a domestic expansion program is the very sizeable lead times required to accomplish significant plant installations. Typically, new plant lead times (go-ahead to beneficial operation) being experienced today are as follows:

TYPICAL 1973 OVERALL PROJECT TIMES
(from go-ahead to production)

Type of Facility	Years
Coal-fired power plant	5-8
Surface coal mine	2-4
Underground coal mine	3-5
Uranium exploration and mine	7-10
Nuclear power plant	9-10
Hydroelectric dam	5-8
Produce oil and gas from new fields	3-10
Produce oil and gas from old fields	1-3

Material and equipment lead times are a major factor in schedules. Most equipment usually is not purchased until plant design is well underway, approvals obtained, and sites acquired. Vendors then must order materials from suppliers and fit the equipment orders into the manufacturing backlog schedule. Suppliers, in turn, must order the raw materials from the primary mills to meet the design specifications.

Prior to the imposition of the oil embargo, material and equipment lead times were already long and were becoming longer in most cases as new plant orders increased during 1972-1973. Since last November, the steel mills supplying sheet, tubular products, and rolled shapes have been supplying distributors on an allocation basis. The result is that lead times have extended considerably because of market instabilities and shortages of raw materials. Indeed, if steel production capacity is not expanded rapidly, beginning immediately, the goals outlined in this report could probably not be attained.

Procurement lead time is defined as the time from the date of placing a purchase order, together with essential information to enable manufacturers to proceed with their equipment engineering and manufacturing, to the date when the completed product is ready for shipment to the construction site. The time required for approval of vendor drawings and transmission of these to the plant engineer-constructor is included.

To these lead times must be added the time required for vendors to prepare quotations in response to inquiries from the engineer-constructor. These typically run from 2 to 8 weeks. Time to perform an engineering and commercial analysis of bids received also must be allowed in order to form the basis of selection of award, and these will run anywhere from 2 to 12 weeks, depending on the magnitude, the complexity, and the necessary approvals. In addition, more time must be added to allow for transportation to the site. Following all of this, the installation or erection times must be added plus testing, checkout, and start-up.

All of this procurement process must be preceded by the overall plant systems design engineering, equipment specification writing, and material requisition preparation. For nuclear equipment, there is usually another 25 to 50 weeks added following placement of purchase orders to allow for formal review of procedures, drawings, AEC review, and approvals before the equipment supplier's engineering can be completed. Furthermore, an additional 3 to 4 weeks for obtaining bids must be allowed for procurement of equipment from Canada, Japan, Australia, Europe, and the United Kingdom.

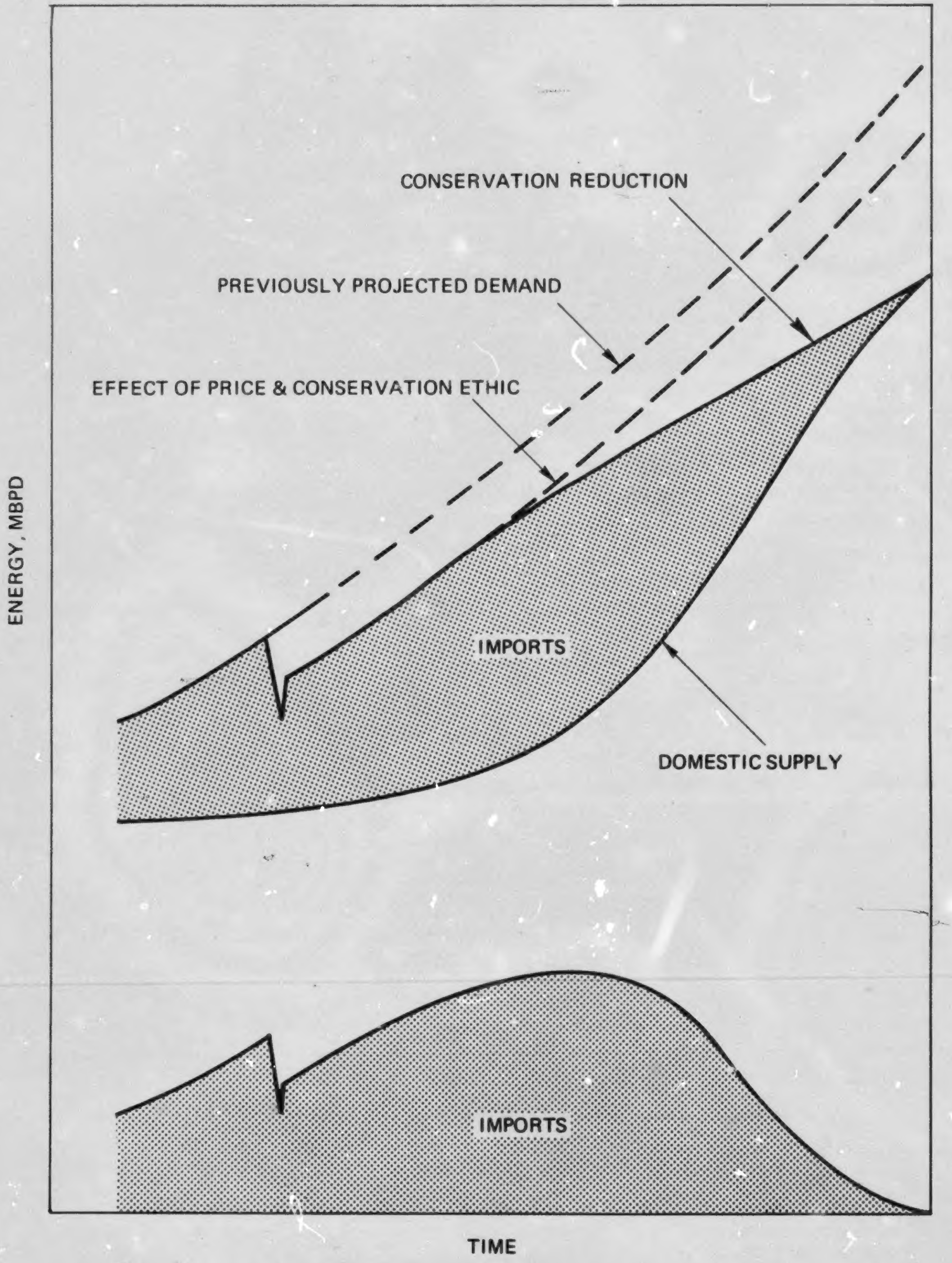
INTERIM SUPPLY AND DEMAND TRENDS

In previous sections, energy supply and demand were discussed in terms of 1973 and 1985. Any solutions to our energy problems must also give careful consideration to the interim trends in both supply and demand. It has been noted that it takes time to develop and build new production facilities. Many sequential time steps are necessary from a go-ahead decision to actual production. With the exception of the electrical power sector, domestic energy facilities have not expanded during the past few years. The nation is now attempting to bring about an upward trend in the supply area, but it will take time to overcome the inertia.

Because of these time factors, the qualitative supply-demand trends for the future will be similar to those shown in Figure 5. The shape of the domestic energy supply curve appears certain to remain flat for the next several years, rising steeply only when the major new sources of energy are brought into production.

On the other hand, the demand curve will tend to increase linearly, if not exponentially, and the reductions resulting from a combination of the "conservation ethic" and higher prices are likely to be constant or perhaps proportional to the total demand. The effect on demand from technical improvements, smaller cars, etc., will tend to increase more rapidly

FIGURE 5 QUALITATIVE SUPPLY/DEMAND TRENDS



in later years and converge on the increased domestic supplies.

While it is not possible to quantify these trends with any precision on the basis of information now available, it would appear that near-term imports will need to rise to a level of 8 to 9 MBPD by 1977-1978 to meet the overall demand in this time period.

Following this peak, it should be possible to gradually reduce imports to the few MBPD that may be needed to satisfy liquid hydrocarbon demands in excess of domestic production capabilities.

More study of this interim period is desirable; but it appears that planning, at least as visualized now, must be based on imports increasing to a level above mid-1973 levels during the 1975-1980 period.

CAPITAL REQUIREMENTS

Capital Demand

The capital requirements of the energy industry are increasing faster than the growth in the consumption of energy and, in turn, faster than the growth in the domestic economy. The capital requirements of the energy industry are also growing faster than the nation's savings. The decade of the 1960's saw a declining capital requirement per unit of energy output, particularly as Middle East oil was developed and as technological advances resulted in economies of scale, especially in electrical generation.

There are three basic reasons for the increased capital demand by the energy industry:

- The demand for energy has been increasing at a rate greater than the increase in overall economic activity as measured by GNP.
- More distant and difficult energy resources are being developed. Oil and gas wells are being drilled deeper and in more remote areas, the Arctic and offshore areas are being developed, and higher capital cost nuclear power plants are being substituted for fossil fuel power plants.
- Finally, inflation increases the cost of all goods and materials necessary for the development of energy resources.

The impact of inflation on energy development merits careful consideration. Inflation will increase capital requirements, but it also will increase incomes, and therefore savings—up to a point. Beyond a certain rate of inflation, savings will begin to diminish. Until this point is reached, however, increases in capital requirements resulting from inflation will be matched by increases in savings available for investment. Therefore, the difficulty of raising capital should not be significantly increased by inflation, unless inflation gets out of hand. Special circumstances in the energy industry must be recognized, however; for example, individual companies may not be able to keep pace with funding requirements by increasing prices.

In considering each sector of the energy industry some of the primary considerations affecting the capital requirements should be noted, though it should be recognized that all sectors of the energy industry are interrelated. Thus, a decline in output of one source of energy will be made up, at least in part, by an increase in the output of an alternate source. Capital requirements would shift accordingly. These requirements are summarized in the following table.

"GUESSTIMATED" U.S. PRODUCTION FACILITY
CAPITAL REQUIREMENTS (billion $)
(1974-1985 Incremental Production)

Oil and gas	160-200
Uranium	11-14
Coal	
Solid	18-24
Synthetics	16-22
Shale oil	3-5
Power supply	
Nuclear generation	90-110
Fossil + renewable generation	60-70
Transmission + distribution	135-165
Total (Rounded)	490-610

The above capital requirements represent the amount of investment (in 1973-1974 dollars) necessary to provide facilities and do not include money required for working capital, dividend, debt service, or other financial needs. Government R&D programs and production facilities (e.g., uranium enrichment) are also not included.

Oil and Gas

At present the major sources of energy in the United States are petroleum and natural gas. Having reached this position of preeminence within the last decade, these will likely continue as the major energy sources at least to 1985. The demand for oil probably will increase provided that adequate supplies are available. It will take major amounts of capital investment to reverse the present downtrend of domestic production.

In petroleum production, capital requirements per unit of output declined during the 1960's as lower cost Middle East resources were developed. The capital required to bring new areas of production on-stream will be significantly higher. In the United States, where capital requirements have recently averaged about $100,000 per well, expenditures per well will reach into the millions of dollars for North Slope development. In offshore work, platforms for oil producing will cost tens of millions of dollars each. Despite these increasing production costs, the drilling rate must be increased at least in proportion to our increasing rate of consumption. Additionally, downstream facilities, such as pipelines and refineries, will increase in capital cost per unit of output. Pipelines and shipping and other modes of transportation increase in cost as the environment becomes more hostile and the distances become longer. Refinery capital costs increase as environmental regulations become more stringent.

As with oil, increased domestic production facilities for natural gas will require increasing capital expenditures. Capital investment will increase as more distant and difficult resources are developed, requiring increased capital expenditure in transmission and distribution facilities.

A review of all the facilities necessary to supply our oil and gas needs between 1974 and 1985 indicates that the capital requirements would be on the order of $200 billion. This represents an average annual expenditure rate almost three times greater than in 1970.

Uranium

Nuclear power generation represents the fastest growing supply of energy, with the result that the capital required for uranium extraction and processing, while relatively modest, will show the greatest growth rate. Currently, nuclear energy is based on use of artificially enriched uranium; and it does not appear likely that other sources of nuclear energy (e.g., breeders, fusion) will be commercially developed until well after 1985.

The current financing requirements for the uranium industry are substantial enough. Uranium mining and milling facilities mostly developed for defense purposes, will soon have to be greatly expanded to meet the demand for nuclear power. Uranium enrichment, currently a government monopoly under the AEC, will have to be greatly expanded to meet civilian needs. Uranium enrichment is likely to emerge as an entirely new private industry with a capitalization of at least $5 billion by 1985, where no such private industry exists today. Fuel fabrication and reprocessing facilities also will be required.

Such developments in the past have not made large demands on private capital markets, but between 1974 and 1985, some $13 billion could be required by the nuclear industry, not including cost of the nuclear power plants.

Coal

Coal is America's most abundant fuel resource and the least capital intensive. With the increasing difficulty of obtaining petroleum and gas supplies, development of coal will be receiving increased attention. Estimates of $10 or even $20 per ton per year to develop a new mine seem small. However, when the projected increase in coal demand of about 660 million tons is considered, which is about equal to current production, together with the associated transportation facilities, the estimated capital to be invested in the development of coal resources between 1974 and 1985 would be about $23 billion, or more than $2 billion per year. This represents about five times the $430 million invested in 1970.

To this point only the capital requirements for production and transportation of solid washed coal have been considered. To these must be added the requirements for the anticipated coal-based synthetics industry, an investment comparable to that required for coal production and transportation.

Electric Utility

Consumption of electricity has grown historically at about 7 percent per year, or about 3 million kilowatts in electric-generating capacity per year. Even if the growth rate declines somewhat in response to conservation measures and the increasing cost of energy, the capacity increases necessary to meet our demands will be large. Currently, the capital required to develop a kilowatt of capacity ranges from $200 to $500, depending on the type of facility, location, and other factors. Including the capital required for transmission and distribution, an estimated $350 billion will be will be needed by the electric utility industry between now and 1985. This represents an annual rate of expenditure of over $30 billion, more than triple the $10 billion invested in 1970.

Total

The total capital requirements for the more readily identifiable portions of the expansion of domestic energy industry facilities are in the range of $490 to $610 billion as shown in the table on page 96. To this, must be added the costs of the not so readily identifiable infrastructure (e.g., railroads, storage facilities, etc.) that is still an essential part of the energy industry. The cost of this infrastructure might add up to 20 percent to the costs given in the above table. The overall total costs of the suggested program therefore could approach $700 billion. This cost covers only the facilities to be in place between now and the end of 1985. While the total includes the capital requirements for facilities already underway and largely financed, it does not include the capital for facilities that must be initiated before 1985 but which would not come into use until after 1985. Therefore, the actual capital requirements during this period could be significantly greater than those indicated.

The figure of $700 billion works out to be an average annual expenditure on the order of $60 billion. For a perspective, this rate can be compared with the total investment in industrial plant and equipment in 1970, for all purposes, of about $100 billion; to the total net funds raised in the money and capital markets this past year of $211 billion; and to the sum of personal savings and retained corporate earnings in 1972 of about $80 billion. While the financial requirement of $60 billion per year is large, with adequate revenues the energy industry should be able to attract the necessary capital resources for the additional energy facilities.

WATER

There has been increasing concern over water use, particularly in the Western United States. Typical of this concern is the newly enacted legislation in the State of Montana, which imposes a 3-year moratorium on water allocations out of the Yellowstone River basin. There can be no doubt that a careful assessment must be made for all water use in areas where the usable supply is likely to be fully allocated in the future. Such an assessment does not automatically preclude new development of energy resources. It may, however, require some trade-offs among potentially competing uses of potable surface waters.

One source of water not in use at the present time, but which may be developed to support energy programs, is non-potable subterranean water. Indeed, one of the development challenges existing in the oil-shale-rich Piceance Basin of Colorado is the presence of saline water aquifers that lie in and above the oil shale beds. This water could supply part of the "process water" needs of an oil shale extraction project. Using current desalinization technology, fresh water could be produced from these saline waters at a relatively high cost of about $200 per acre-foot. Unless the nonpotable waters can be exploited in this way, certain areas may be precluded from energy conversion activities.

A 1973 study entitled "Rehabilitation Potential of Western Coal Lands" by the National Research Council of NAS/NAE[31] found that water may indeed be a limiting factor in the exploitation of western coal in certain areas. The following summary is quoted from that report:

> The shortage of water is a major factor in planning for future development of coal reserves in the American West. Although we conclude that enough water is available for mining and rehabilitation at most sites, not enough water exists for large-scale conversion of coal to other energy forms (e.g., gasifica-

> tion or steam electric power). The potential environmental and social aspects of the use of this water for large-scale energy conversion projects would exceed by far the anticipated impact of mining alone. We recommend that alternative locations be considered for energy conversion facilities and that adequate evaluations be made of the options (including rehabilitation) for the various local uses of the available water.

Therefore, water use planning will be essential for the production of oil from shale or gas from coal. The mining operations should, in general, be feasible, and shale conversion will need to be done essentially on site because of the great bulk of rock involved.

With respect to coal, water for conversion to gas may be available in some locations, and in other places it may be possible to purchase existing water rights because of the higher economic advantage of this use. However, implications for the existing social and economic structure, which is based largely on irrigation, must be considered. In many instances, mined coal will need to be shipped in solid or slurry form for conversion at sites where water is more abundant.

Midwestern and eastern states also have substantial coal reserves, although generally of higher cost per Btu than western coal. Many of these midwestern and eastern locations have ample water available for conversion, but they have the problem of legally assuring water availability for consumptive use under their prevailing riparian laws. It is generally believed that these states will need to enact water permit laws that can give assurance of water availability.

In summary, the Task Force concludes that overall water availability, while a serious concern, should not deter the development of oil from shale or gas from coal in the production amounts forecast as being possible by 1985. In the West it may be necessary to employ alternative process cooling methods, and, in many instances, it may be necessary to export the coal to eastern locations where water is available. Within this overall assessment, site investigations will need to be conducted on a case-by-case basis.

MANPOWER

The Task Force was unable to find any carefully prepared manpower estimates relating specifically to the energy industries. The 1973 data are based on Bureau of Labor Statistics information and, in some cases, include unpublished Bureau adjustment. The projections are based on Task Force estimates of possible increases by supply sector and projected trends in productivity. The purpose of the data, however, is not to produce precise estimates of manpower requirements, but rather to highlight areas where shortages are likely to occur.

There are three areas of likely shortages. Within the energy industries, it is likely that only coal miners might be in short supply during the period. In the other operating industries, productivity trends appear likely to keep the increases in requirements within reasonable bounds. Other areas where serious shortages are likely to occur are in all classes of engineering personnel and all classes of skilled construction craftsmen. The following parts of this section will cover each of these areas.

The estimates for operating industries are summarized in the following table:

ESTIMATED TOTAL OPERATING MANPOWER REQUIREMENTS

Industry	1973 Population	1985 Population	Additions 1974-1985
Oil and gas	456,000	495,000	39,000
Coal mining	165,000	290,000	125,000
Power generation	710,000	755,000	45,000
Shale and synthetics	-	10,000	10,000
Energy transportation	76,000	86,000	10,000
Total (primary only)	1,407,000	1,636,000	239,000

In coal, annual output per man increased from 2,230 tons in 1960 to 4,140 in 1970, and then declined to 3,420 in 1973. Assuming an increase in productivity to 4,000 in 1985, employment would increase to 290,000 if the Task Force goal of 11.7 MBPD equivalent is met in 1985. This figure is likely to be high if western surface coal operations result in much higher than the 4,000 tons per man level of productivity and if mine mechanization offsets the lower productivity that has accompanied recent Occupational Safety and Health Act rulings.

In oil and gas there are two categories, crude production and petroleum products manufacturing. Productivity increases have been quite sharp in both categories. From 1960 to 1973, productivity increased by more than 50 percent in crude production. This increase was due mainly to larger scale production facilities, automated process control, and improved technology. Further increase in productivity is not likely since most added production will be from deeper wells, a greater proportion of offshore wells in deeper water, and will involve increased environmental protection measures. For the estimated 27 MBPD of oil and equivalents, the Task Force projects that 330,000 employees will be required by 1985. For petroleum products manufacturing, productivity gains have been even more favorable and, based on Bureau of Labor Statistics and Federal Reserve Board figures, increased by almost 90 percent in the 1960 to 1973 period. As with crude oil and gas production, the future does not offer further significant productivity gains. The Task Force estimate for petroleum products manufacturing for 1985 is about 165,000 employees.

Employment in the electric, gas, and steam utility industries has remained essentially constant, increasing at less than 1/2 percent per year in the face of an approximate 7 percent increase in output. Assuming that this trend continues, employment should increase slightly from 710,000 to 755,000 by 1985.

Engineers

The ability to expand the energy industries will depend heavily on the numbers, qualifications, and capabilities of engineers, designers, technicians, and project managers. Qualified engineers are in short supply now, and the situation will worsen in the years ahead. The following table summarizes the increase in requirements expected in the operating industries as well as the engineering-construction industry by 1980. The year 1980 was selected because most of the engineering activity would have to be underway by 1980, if the facilities discussed in this report are to be in operation by 1985. The estimates indicate that a 40 percent increase will be required by 1980. These estimates were derived by applying ratios of engineers to the total employee population for each of the operating industries. For 1980, the ratios were projected by the Bureau of Labor Statistics and were based on a continuation of the trend toward a greater percentage of engineers in the employee population. It should be emphasized that these are rough estimates and only indicate trends in requirements.

ESTIMATED ENGINEERING MANPOWER IN ENERGY INDUSTRY
(Total Including Construction)

Discipline	1973 Population	1980 Population
Civil	15,640	24,350
Mechanical	17,320	26,350
Electrical	26,110	34,940
Mining	7,920	9,830
Chemical	7,410	9,240
Total (Primary only)	74,400	104,700

The outlook for the supply of engineers must be tempered by the fact that enrollment in engineering schools is not keeping up with industry requirements. The class entering college in 1972 was the smallest in 20 years.

The situation may be improved by transfers of engineers from fields outside the energy industries. The engineers employed by the energy industries are less than 10 percent of total U.S. engineering employment. All engineering curricula contain the fundamentals of physical sciences and applications of engineering methods to specific problems. Even though an engineer was graduated in civil or mechanical engineering, a special training program of not more than 6 months would prepare him to undertake petroleum or mining engineering work. With engineers in short supply now and no relief in sight, special training and reorganization of engineering assignments would be needed to accomplish the design engineering work required in the next few years to achieve the on-line capacities estimated for 1985. The alternative is simply not being able to achieve such levels.

Construction Craftsmen

The following table includes a set of estimates of the skilled construction workers required in the "industrial" construction areas. Industrial construction for this purpose includes such facilities as oil refineries, metallurgical process plants, syngas and liquid natural gas (LNG) facilities, major pipelines, and similar projects. Common to these industrial facilities is the employment of a similar mix of construction craftsmen such as pipefitters, welders, electricians, and boilermakers. The estimates indicate that requirements for these craftsmen may more than double in the next 12 years. While these numbers may be high, they indicate that the increasing requirements will be a serious problem, even if the estimate is off by as much as 20 percent.

ESTIMATE OF SKILLED CONSTRUCTION WORKERS REQUIRED

Trade	1973	1985	Additions
Electricians	26,000	65,000	39,000
Pipefitters	41,000	91,000	50,000
Boilermakers	19,000	22,000	3,000
Laborers	53,000	139,000	86,000
Operating engineers	10,000	24,000	14,000
Total	149,000	341,000	192,000

3

The seriousness of the problem is underscored by the slow increase in the membership of building trade unions of the AFL-CIO, the major source of skilled craftsmen for the industrial construction sector. The data in the following table were released by the AFL-CIO in October 1973. They indicate that even in the fastest growing union, electrical workers, the increase is less than 3 percent per year compounded annually. These figures include craftsmen in construction areas other than the industrial category, and they include a large number of craftsmen in manufacturing industries such as electrical manufacturing and pipe fabrication. The workers in the "industrial" construction category constitute less than 10 percent of the total in the specified crafts. There is some interchangeability between these occupations and industrial construction, but it probably would be insufficient to provide more than minor relief to the anticipated shortage.

BUILDING TRADES MEMBERSHIP

	1965	1973	Percent increase
Boilermakers	108,000	115,000	6.5
Electrical workers	616,000	779,000	26
Ironworkers	132,000	160,000	21
Laborers	403,000	475,000	17
Pipefitters and plumbers	217,000	228,000	5
Operating engineers	270,000	300,000	11
Total	1,746,000	2,117,000	21

Numbers of workers and training are only part of the problem of worker availability. Mobility of labor, particularly in the construction trades, has been lessening in recent years. The required incentives for people to relocate will undoubtedly increase, with resultant increases in cost.

Two final points, perhaps, should be made. First, no discussion of manpower can be complete without a discussion of productivity. There has been a serious decline in building construction labor productivity in recent years, and this has been the topic of many discussions on union work rules. Some method of reversing such trends must be found.

The second point is that this country is dependent on energy and productive machines to maintain competitive status in world markets and to provide jobs for an expanding labor force. To continue to supply the industrial economy with its energy needs, the energy industry must be able to attract a large share of the most talented people from our universities. Current enrollment statistics indicate a trend away from the disciplines most needed in the energy industries. Whatever the cause of this situation, steps must be taken to provide these people with greater personal satisfaction from a career in these industries, and an understanding of the great benefits to all of society that such careers provide.

The Task Force believes that critical shortages can be avoided if programs by educators and industry are begun now with appropriate government assistance. These programs should include elements along the following lines:

o Increase mechanization of underground coal mines so as to upgrade the quality of jobs from unskilled and semiskilled to skilled work.

o Increase the enrollment of students in engineering schools. A variety of programs must be developed for the motivation and guidance of students into the engineering profession.

o Establish programs to retrain and transfer engineers from occupations where demand is declining to occupations in the energy industries.

o Work with the building trades to increase membership in apprentice programs and shorten the apprentice time period. Programs such as this have been very successful when established by the United Association of Plumbers and Pipefitters and industry groups.

o Provide training programs for craftsmen in manufacturing industries and nonindustrial construction to upgrade their skills for industrial construction work.

ENVIRONMENT

Extraction of domestic energy resources and conversion to useful forms will have implications for the environment. These can be damaging and disruptive if care is not taken. Environmental impact must be considered in choosing among alternative methods for attaining the Nation's energy goals. In many instances, no alternatives may be available to avoid some deleterious effects, and difficult priority decisions will have to be made. For the most part, however, the Task Force believes that with diligent care, a healthy environment can be assured at a cost the Nation can afford.

In surface mining of coal, land reclamation is a growing environmental concern. Similar concerns apply to the recovery of oil from shale by surface retorting methods. Expanded offshore drilling for oil and gas and ocean-bottom pipelines may bring problems of oil leaks. Such risks must be considered along with those of the continued use of supertankers for the importation of oil. Nuclear power plants pose problems of safety and waste disposal, and these must be dealt with.

Atmospheric Sulfur Dioxide and Particulates

Recent improvements in urban air quality have resulted from the increased use of cleaner burning fuels. Construction of a significant number of new coal-burning power plants could reverse this trend unless adequate low-sulfur coal is used or unless reliable stack gas SO_2 removal equipment is employed.

Control of particulates by precipitators is an established technology. By contrast, stack gas desulfurization has not been demonstrated to be reliable on a commercial scale. There do not appear to be any basic scientific or engineering barriers to ultimate success, and the Task Force believes that reliable processes could be available within a few years, given adequate support and demonstration testing. In the meantime, temporary variances or changes in regulations could be made for locations where the public health is not endangered.

Automobile Emissions

Automobile emissions are controlled by the provisions of the Clean Air Act of 1970. Control of emissions involves either the use of expensive catalytic converters or a 10 to 15 percent direct fuel consumption penalty.[5] The removal of lead from gasoline presently involves additional consumption penalties.

There is a belief today in some quarters that the Clean Air Act should be amended to reflect the new cost-benefit information that has been developed in the past 4 years. The Task Force takes no position on this difficult policy question. However, the provisions of the law as it now stands seems likely to increase the consumption of liquid fuels. It is clear, nevertheless, that an increasing percentage of smaller, lightweight, low-horsepower cars will have a major beneficial impact on both energy demand levels and atmospheric pollution levels.

Studies now being carried out indicate that the best likely course may be to hold automobile exhaust emission standards at values of 0.4 gram per mile for hydrocarbons, approximately 5 to 6 grams per mile for carbon monoxide, and no less than 1.5 grams per mile for nitrogen oxides.[32] It would appear that these standards can be met by 1976 without significant penalties on fuel economy.

A combination of market forces and federal legislation could drive the U.S. auto industry toward smaller, lighter, and more efficient vehicles. Thus, a combined auto emission/fuel economy strategy is considered an essential part of any overall energy program over the next 10 years.

Land Reclamation

As discussed in Chapter 4, coal and its synthetic gases and liquids probably will play an increasingly important role in providing our hydrocarbon needs in the 1980's and beyond. This raises the difficult environmental issue of coal mine land reclamation, and the problem of the disposal of solid and liquid residual products, such as sulfur, from gasification and liquefaction plants.

Experience in West Germany has demonstrated that in temperate climates top soil can be removed, set aside and preserved, and later restored. In a project near Cologne, treated sewage is pumped into the land after this operation to provide nutrients. As a result, the soil is richer than it was before the strip mining operation began.[33]

Knowledge of desert ecology is still rudimentary. Considerable research and development is required before we can fully understand the extent to which reclamation in arid climates, such as the Southwestern United States, is possible and the proper methods for its conduct.

The costs of land reclamation are also difficult to estimate at the present time. The Task Force believes that intensified efforts are needed to improve understanding of land reclamation techniques and costs. A study of actual experiences to date with various procedures is a first requirement.

Offshore Oil and Gas

Environmental concerns have been expressed regarding offshore petroleum operations on the East Coast, production from offshore Santa Barbara, and leasing of tracts in the Gulf of Mexico. Concern usually focuses on the effects of major well blowouts, but some attention has been given as well to minor repetitive discharges from operations.

Since 1948, some 18,000 offshore wells have been drilled in the United States, of which 3 have released large quantities of petroleum liquids into the ocean. Only one, the Santa Barbara accident, resulted in severe pollution of the shores. That was of a temporary nature and the area is recovering.[34] The U.S. Geological Survey and other government agencies recently established stringent equipment and operating regulations. As a result, the environmental hazards of offshore oil drilling have been reduced, although some leakage risk remains.

One factor that is sometimes overlooked is the trade-off between offshore drilling for oil and the importation of oil by tankers. The environmental dangers of oil spillage from supertanker operations must be matched against the risks in offshore oil drilling and undersea pipelines.

Nuclear

Most of the environmental aspects of nuclear power have been treated in considerable detail in Chapter 5. However, some further points are pertinent.

Emergency Core Cooling. The adequacy of emergency core cooling systems to perform under all conditions remains questionable to some. Recently revised AEC criteria should do much to reduce the possibility of a loss-of-coolant accident. Continued R&D efforts should increase public confidence in such systems.

Seismic Effects. The adequacy of seismic design and construction criteria has also been questioned by some. Efforts to improve the state of the art in this regard should be intensified. Siting of nuclear plants near or adjacent to long-active faults should always be approached with great caution.

Sabotage. Additional standards development is needed to further reduce the possibility of nuclear reactor damage by willful acts.

Safeguards. Development of additional security measures can further reduce the opportunity for diversion of plutonium and enriched uranium materials.

Long-Term Radioactive Waste Storage. Temporary storage facilities for radioactive wastes can be built, but there is still no fully satisfactory method for permanent disposal. Salt formations in the Southwestern United States are promising, however.

Siting. Vermont, Oregon, and Washington have established procedures for centralized siting approvals. Similar actions by other states would standardize the approval process and speed up the construction of nuclear plants on appropriate sites, provided that these approvals are acceptable to all levels of government.

The Task Force believes that adequate solutions have been established for the following: Routine release of low-level radioactive effluents; transportation of nuclear fuel and radioactive wastes; uranium mining and processing; fuel fabrication; and intermediate-term storage of high-level radioactive wastes, pending an agreement on the best disposal technique.

One major difference in viewpoint exists, however. Whereas Chapter 5 urges that all public hearings be abandoned in the operating permit proceedings, at least one member of the Task Force believes that in some cases public hearings should be continued to deal with identified but unresolved issues.

TECHNOLOGY

The objective of this study was to examine production capabilities, not technological innovations. This does not mean that developments in supporting technology do not need to continue or that major R&D programs should not be undertaken in the next 12 years.

On the contrary, these efforts are extremely important and must be undertaken not only to create the near-term production facilities, but also to achieve more economical processes and new energy technologies for the longer term. Many supporting programs involving metallurgy, safety, process technology improvements, restoration, transmission, equipment reliability, and many more areas will be absolutely vital for attaining lower costs.

In addition, R&D programs for the long term must be carried on vigorously by both industry and government. Sooner or later, we must reduce burning of fossil fuels, and the basic R&D toward that end must be started now. Breeder reactors will be needed to assure continued nuclear energy resource availability; coal liquefaction will be needed to assure hydrocarbon fuels for our transportation systems; and geothermal, solar, and fusion resources need to be developed to assure clean energy supplies for the next century. The Task Force believes that the quality of life in an increasingly high-technology world hinges on the development of new energy sources and, therefore, recommends an aggressive R&D program in this area.

The Task Force has not endeavored to suggest relative priorities among the various long-range R&D efforts or to assert any specific level of priorities for long-term vs short-term and mid-term. However, there may be conflicting demands, particularly for funds; for scientific, engineering, management, and possibly construction manpower; and for some equipment and materials. Consideration will surely have to be given to reducing the rate of effort on some long-range programs or less important programs in order to deal with the short-range situation, which, if not resolved, could restrict our ability as a Nation to deal with the long-range objectives.

Chapter 9

IMPLEMENTATION

This chapter summarizes the framework and assumptions in this report regarding government and industrial actions that could encourage the maximum beneficial expansion of domestic energy production. These actions are intended to be illustrative; the Task Force neither recommends them specifically nor judges that they are best or uniquely suited for reducing dependence on imports. The Task Force does believe that they are examples of actions that could significantly increase our domestic energy supplies. The Task Force also believes that past policies and postures by government and industry are not adequate to cope with the energy supply and demand problems during the next decade and beyond.

OVERVIEW OF MARKET AND ROLES

The Energy Market

Our domestic levels of energy supplies and consumption reflect the market decisions of many individuals and institutions. In turn, these decisions result from many separate perspectives of opportunities and risks, needs and availabilities, and the impacts of future governmental policies. Although these decisions and perspectives are generally well intentioned, as measured by consistency with the institutions' own objectives and responsibilities, their interactions have led to the present situation.

If present energy levels are judged to be unsatisfactory, but free, individual market choices are considered worthy of being preserved, then it would follow that market perspectives need to be redirected. This process has already begun, and the underlying economic incentives are discussed in the following section.

Left to themselves, economic incentives and redirected market perspectives would create a new equilibrium of supply and consumption. It does not necessarily follow that this new equilibrium would be entirely consistent with national goals for reduced demands and imports. Thus, if energy self-sufficiency is a goal of public policy, then the government must consider how it can effectively act to realize that goal. It could limit itself to traditional types of actions for which it is well qualified by experience. Alternatively, it could take on new types of actions, with the added burdens of developing competence in these new areas of responsibility.

The Task Force assumes that the Nation would prefer to avoid new governmental responsibilities whenever there is a reasonable expectation that they are unnecessary to the goal. Consequently, the Task Force assumptions emphasize traditional roles and responsibilities.

Traditional Roles

Governments at federal, state, and local levels provide the overall framework for the energy market. This structure is manifested through laws, regulations, licensing procedures, procurement practices, and taxation policies. Government has traditionally left to private enterprise the tasks of exploring, producing, transporting, converting, and marketing most of the energy forms in the United States. Although many federal agencies support energy R&D activities relating to the respective agency missions, private funds have provided for most of the energy R&D in this country in the past. In the fossil fuel field, in particular, the great majority of useful results have come from private efforts.

In the present situation industry has the bulk of resources, the experienced personnel, the technical knowledge, and the facilities for implementing most programs for increasing the supply of energy. Government can provide needed support by clearing "roadblocks" to increased energy production and by fostering a favorable climate to ensure adequate incentives to the investor and adequate safeguards to the consumer and the public.

ECONOMIC INCENTIVES

Economic incentives are the driving force that operate the industrial system in the United States. Government actions should allow the economic incentives to operate fully to produce the desired results, while preventing or reducing inequities where these may arise. This is, at best, a difficult and imperfect process.

As more costly processes are utilized, as lower grades of resources are developed, and as provisions are made to protect the environment, the costs of added energy sources are increased. When the high cost of borrowing money and the rapid increases in construction and operating costs are taken into account, the costs of energy must increase, particularly for new sources. The investor in bonds or common stock who justifies his investment by anticipated returns perhaps in several years, will only do so if it is a reasonable gamble -- and the more the gamble, the higher the return he will expect.

A facet of the problem can be illustrated by the calculation that the opportunity to receive $100 in 20 years is worth spending no more than $17.84 today. That is, today's investment of $17.84 at a prime rate of 9 percent (and almost 100 percent certainty of repayment) yields $100 after 20 years. It is difficult to justify long-range, higher-risk investments that promise no greater returns than an investment with less risk and paying the minimum prime rate. This is true whether the subject is prospecting for minerals, developing oil and gas fields, or developing a new chemical process. Expected returns on energy investments must be competitive with alternative investments in order to attract adequate financing.

Increased prices for imported oil and natural gas in the foreseeable future make it reasonable to seek to reduce imports by substituting domestic resources if they can be developed and produced at no more than the cost of imported sources, which today are of the order of $9 to $10 per barrel of oil. These seem unlikely to drop below $8 or $9 per barrel (in 1974 dollars) and may increase. The development and production of energy with costs above these levels -- as may be the case, for example, for oil from coal -- will require government financial assistance in some form, unless it is considered desirable to allow energy prices for at least a substantial fraction of all energy sources to rise to higher levels for national security reasons. This would probably be very expensive indeed and would cause problems of social equity.

Marginal cost theory, while of general application, does not, of course, hold in an imperfect market such as actually exists; does not take into account the diversity of geographical areas and possibilities for substitution; and is generally very much affected and distorted by governmental regulations and price controls, as well as taxation patterns. Nevertheless, it does provide a reasonably valid general picture of the effect and nature of economic incentives and the manner in which they apply in energy supply and demand in the United States.

While higher prices will have a direct effect on most energy development and production activities in terms of providing revenues to justify the added costs in a fairly direct manner, the effect on the consumer is considerably diluted. The effect of increased energy costs on the consumer should not be as great as that of increased prices on the producer. While the increased costs of new production are present, the consumer pays a mixture of old and new costs. For example, the costs of transport, conversion, and distribution are often a large part of the total costs. They are, however, relatively constant and generally a mixture of old and new actual costs. Further, they are often a large proportion of the total costs. In addition, the consumer may have some options as to interchangeability of fuels and/or of suppliers, which give him more flexibility.

The recent high bids for oil shale developmental tracts and the unexpected increase in sales of smaller cars are good examples of ways in which economic incentives are already operating to the benefit of the energy situation. On the other hand, there seems to be no way in which research such as that on nuclear fusion or fast breeder reactors is likely to be carried out unless supported to a very large extent by government funding. As noted, coal liquefaction, which could begin to be available on a large-scale commercial basis in 10 to 12 years, if developed aggressively in the meantime, seems an intermediate case deserving of special study.

ILLUSTRATIONS OF GOVERNMENT ACTIONS

The Task Force believes that governmental action could overcome major obstacles to industrial initiatives and encourage long-term developments that exceed the private sector's prudent risk. Governmental assistance could take many different forms, some of which are illustrated by the following. These illustrations are only examples. It should be borne in mind that government actions can bring unanticipated problems as well as benefits and that many actions are difficult or impossible to reverse.

o Remove Constraints. The government could remove or alleviate disincentives to domestic energy development that result from existing laws and regulations. Example: The government could deregulate the wellhead price of natural gas so that gas prices could seek parity with other fuels.

o Reduce Risk. The government could accept or share the risk with private firms in special situations involving the development of new technology that appears attractive over the long run but in which an unsuccessful result could mean bankruptcy for the firm and disaster for the employees, the investors, and the community. Example: The first firm to demonstrate the feasibility of a new technology is not necessarily able, even under the best of circumstances, to recover the R&D costs incurred in deriving that technology. A firm that is "second in the market" has the advantage of knowing that the technological, economic, and marketing problems are solvable.

o Support Development. The government could support the development in government, university, or private facilities of long-range energy technologies that, while potentially of general economic and social benefit, are not acceptable commercial risks in the near-term because of uncertainties of success, foreseeable costs exceeding projected market prices, or the long time involved in successful development. Example: The government might support effort in coal liquefaction because of the high development cost, long period required, and the estimated production costs, which, while perhaps acceptable and necessary in 15 years or so to provide adequate oil supplies, may be higher than oil costs foreseeable now.

- Compile Data. The government could compile data on the present status and future projections of energy supplies and consumption to help decision makers interpret the consequences of alternative policies and actions.
- Disseminate Information. The government could provide information to consumers regarding the relative costs and benefits of energy-consuming devices. Example: The Environmental Protection Agency action in publicizing the relative gas consumption of automobiles allows the new car purchaser to estimate the fuel consumption of a prospective purchase and to make trade-offs with other desired features.
- Establish Standards. The government could promulgate standards aimed at protecting the public safety or welfare in those situations where an informed market does not operate. Example A: Building standards specify the minimum insulation for residential and commercial buildings. Most consumers cannot readily judge the adequacy of insulation in buildings. Example B: Air quality standards are designed to insure that air pollution does not endanger human health. Air is a free good, in common ownership, and not subject to market operations.
- Taxes. The government establishes corporate income and various other taxes, duties, fees, etc., and through these can provide incentives as well as disincentives to producers, converters, transporters, and consumers of energy, whether from domestic or foreign sources. Special tax benefits for some segments of the energy industry may, when passed on to the consumer, stimulate overconsumption of one form of energy. Other tax considerations may lead to accelerating or decelerating the search for and development of energy resources. While the impact of taxation policy on industry and industrial developments is profound, in the end it is the consumer who is most affected by these taxes and who, in the ultimate analysis, pays them one way or another.
- Manage Resources. The government's responsibility includes management and conservation of public lands and resources for the benefits of both present and future generations. This management responsibility implies choices between making available federal fuel bearing lands or oil and gas sites for private development versus alternative uses of the same resources.

FEDERAL GOVERNMENT ORGANIZATION

Congress, in response to proposals by the Administration and others, is considering the establishment of a permanent central organization in the federal government to deal with energy: Resources, recovery, conversion, transport, and utilization. Such a central organization, especially if at a high level, would make it easier to attract and hold the outstanding leadership and expertise required for the difficult tasks involved in implementing the federal energy role and would provide recognition of the importance of energy issues to the Administration and the Congress.

The Task Force concludes that a high-level federal energy organization is desirable but does not recommend any specific organizational structure, since such structures are best evaluated by the Administration and by Congress.

The Task Force offers several observations of the functions of such an organization or organizations that would be consistent with the governmental role and actions discussed in earlier sections:

o Collection, development, evaluation, and publication of projections of energy demands and supplies.

o Development of national energy policies for consideration by the Executive Department and the Congress, and coordination of policy development with other federal, state, and local government agencies as well as the energy industries.

o Development of strategies for assuring adequate energy supplies at reasonable costs with minimum impact on the environment.

o Development and implementation of plans for conserving energy and measures for increasing efficiency of energy utilization.

o Implementation of allocation and rationing programs if required.

o Planning and direct assistance in removing institutional roadblocks to developing and using energy resources.

o Development and publication of data on resource requirements, availability, and critical areas for overall energy programs and specific segments, including engineering; scientific; and construction manpower, equipment, and manufacturing capabilities; materials, etc. Assistance with provision of essential resources to high-priority energy projects.

o Development and application of financial incentives where clearly required, including development and overall surveillance of joint government-industry programs in areas requiring government financial support.

o Coordination, assistance, and resolution of critical problems in areas of environment effects, water supply and allocation, land use, etc.

o Development and coordination of international programs in energy areas.

o Support of research and development where the risk is too great for private investors.

o Coordination of programs for long-range and basic research in energy areas.

o Provision for information dissemination and advice to the general public and special groups.

In the energy area, there are many long-range and some short-range research and development activities that can be carried out by universities and government agencies, but those institutions are quite inappropriate for a large class of research and development problems that belong properly in industry only. Such problems are those that are so closely related to the needs of prospective suppliers and users as to benefit from close association, throughout their active pursuit, with industry; or those practical problems in which industry has special competence; or problems involving pilot-plant research and development in which industrial know-how, scheduling, and intergroup cooperation are of special value. These are best carried out in a commercial, real-world environment. Academic and basic research, carried out in universities or government agencies, is of importance in providing supplemental or backup data, but guidance of projects to commercial fruition is most often the province of industry.

Developments such as coal liquefaction and fast breeder reactors are examples of those that must be closely tied to industrial requirements and capabilities.

Development activities are enhanced by strong interactions with the regulating agencies (FPC, AEC, EPA, etc.). They can assist the central energy organization to attain its objective of assuring adequate supplies of energy in the forms required at reasonable prices and with proper safeguards for the environment.

INDUSTRIAL ACTIONS

With a well-defined and stable set of national objectives and policies, arrangements for removing or alleviating roadblocks, mechanisms for speedy resolution of environmental or other similar issues, and a focal point in the federal government for assistance, information, and actions, the various segments of the energy industries should be able to accelerate and expand efforts to provide added energy supplies in the needed forms and, where desired, initiate new projects. The driving force will be largely economic, and the government will continue to play its traditional role; but hopefully, mutual understanding of the objectives and problems -- along with coordination and cooperation -- will result in the energy supplies (and reduction in demand) judged to be needed by the nation. A common sense of national purpose and urgency, rather than one of dissension and conflict, is essential.

In this context, industry will have many demanding tasks to carry out in a rapid, effective, and economical manner. Among them are the following:

o Financing. Expansion of energy facilities will require very large amounts of money from internal funds, equity funding (stock), and bonds or loans. These funds can be obtained if the industries have stable and adequate revenue to cover their costs, repay their loans or bonds, and provide the stockholders with adequate return.

o Planning. In all segments and at all levels, industry will have to carry out rapid and detailed planning in response to new objectives and goals and within any new frameworks evolved in response to the energy supply-demand situation.

o Management. Once detailed plans are evolved and critical problems are identified, the various organizations -- along with their managers and key personnel -- will have to be reorganized and redirected as necessary to undertake the various tasks on an urgent basis, whether these are new exploration programs, new mines, new oil refineries, construction of facilities, operation of new mines or plants, manufacturing of new equipment, or the providing of development support. The industrial structure would probably be the same, but substantial reorganization and change would surely evolve and experienced planners and managers would likely be at a premium.

o Manpower. In addition to managers and planners, there will probably be a critical shortage of many types of manpower, particularly engineers and skilled construction workers. Major programs would be needed to make more efficient and effective use of available manpower, to utilize less skilled manpower where practicable, and to train more personnel as rapidly as possible.

o Environment. Full consideration will have to be given to environmental effects and at arriving at reasonable cost/benefit decisions for industrial programs having an impact on the environment. Close cooperation with government should allow quicker decisions if industry has done an adequate job of considering the issues. Similar consideration would be true in safety areas, land use questions, etc.

o Development. Many energy programs will require substantial support in terms of development, and effort may need to be diverted from other research and development activities to provide such support.

o Public Information. Industry must establish and maintain credibility with the public (as well as with the government) in order for the government-industry cooperation to be possible and effective.

Chapter 10

CONCLUSIONS

It is important to recognize that there is a real and increasing gap between the present energy production and essentially all projections of future energy requirements in the United States for the next decade and beyond. This gap is now expected to be closed by large imports of oil and gas. It does not really matter whether this situation is called an energy "crisis" or an energy "problem." The important point is that it is real and will not go away if simply endured or ignored.

The situation will only be alleviated or corrected to the extent desired by sensible, cooperative actions in the public and private sectors. While economic and market forces are acting even now to produce additional supplies and reduce demand, these alone are not likely to be sufficient to meet our national objectives, particularly if the time factors are taken into account. All alternatives, except simply "doing with less," take an appreciable time to become effective.

The options that are available to increase domestic supplies and reduce demand are not numerous. The important ones have been included in this report. There are no other solutions that are likely to appear suddenly. Research and development is not likely to generate new energy sources that can be applied on a large scale in the time period under consideration, and certainly should not be counted on.

All of the solutions have certain costs, not only in money, but also in manpower, materials, equipment, water, and other resources, as well as in various environmental effects. There may also be short- and long-term economic and social implications. Policy judgments on the overall desirability of the various programs are beyond the scope of this report. However, it must be stressed that any policy to substantially improve the domestic supply/demand situation in the years ahead will require the utilization, to a greater or lesser extent, of many, or, indeed, all of the programs described in this report.

Providing additional domestic energy supplies during the next decade or so does not require the solution of significant technical problems, but will, in some cases, call for substantial development support. The interrelationship between government and private institutions is the major problem. The government must establish a well-defined national energy policy and carry out its licensing and regulatory actions so as to attract large sums of private capital for investment in the programs while, at the same time, protecting the public interest.

Early and positive decisions and actions are required. This report outlines some of the decisions and actions that need to be considered. The ability of the United States to find realistic and workable solutions will determine the time and cost of establishing whatever level of energy supplies is deemed desirable with the least overall economic, environmental, and social complications. More specifically:

o Domestic energy demands -- despite conservation incentives, higher energy prices, technological changes such as smaller cars, and more efficient industrial processes -- will continue to increase steadily for the foreseeable future.

o Domestic energy supplies, growing at a rate less than that of demand, have in recent years essentially reached a plateau and only provide about 85 percent of the current demand, the balance coming from increasing imports of oil and some gas.

o Projections of domestic supply and demand made before the fall of 1973 predicted the need for large and increasing imports of oil and gas with attendant problems of potential supply interruptions, higher costs, increasing effects on balance of payments, and questions of worldwide productive capacity for oil. The oil import embargo in late 1973 and the concurrent sharp increase in oil prices by essentially all of the oil-exporting nations has produced a substantial change in U.S. and worldwide thinking and leads to further consideration of means for reducing energy demands in the United States and increasing domestic energy production.

o While domestic energy production cannot be increased abruptly, in time it can be expanded over the present levels or those previously projected for 1985. Production levels of about 49 MBPD by 1985 seem feasible in contrast to projections of about 40 MBPD made in mid-1973 and actual 1973 levels of about 30 MBPD. However, the costs will be high, and such a program will strain U.S. resources and will place considerable stress on the environment.

o Decreases in demand due to the development of a "conservation ethic" and the direct effect of higher prices could be significant. It is difficult to predict the size of effects or the length of time over which these effects may persist. Decreases in demand due to such measures as small cars; better insulation in homes, buildings, and industry; improved industrial processes; and more efficient space heating and cooling will probably have a larger effect, but cannot reduce demand significantly for 8 to 10 years.

o It is believed that increases in domestic production could be achieved by about 1985, if desired, which would bring domestic supply into rough balance with reduced demand without resort to a "crash" approach. However, it would be necessary to initiate urgent work on essentially all practical measures for increasing production of oil, gas, coal, and nuclear energy immediately. Such a program would require high priorities and close cooperation by government and industry.

o At the same time, programs for reducing demand would also have to receive urgent, large-scale, and continuing attention and publicity by government and industry.

o Despite such domestic programs for decreasing demand and increasing domestic production, imports of oil and gas will probably have to increase over the next several years to levels higher than the 1973 peak before they can decrease in later years.

o Attainment of minimum net imports by about 1985 would require not only that the programs be started promptly with full and continued support but also that they be successfully finished on schedule. There is little or no provision for contingencies in the estimates.

o Domestic energy supply increases must be brought about by industry, largely stimulated by economic incentives, but with the close cooperation of government to facilitate the most rapid and orderly implementation of new projects.

o Direct government financial assistance may be needed in some cases where prevailing price levels do not appear adequate to justify longer-range developments and/or technological risks and where it would be undesirable to let marginal prices increase to the levels required. Coal liquefaction and oil shale may be in this category.

o The cost of such a total program, including all resources, may not be acceptable or feasible. For example, the investment would need to average about twice the present annual rate over the next 12 years. This program would require extensive use of engineering and scientific manpower, construction workers, water supplies, materials, and equipment. The environmental impact may also be a limiting factor.

o Zero energy imports may not be desirable from an international point of view.

o Successful achievement of these programs would produce less volume of oil than is now consumed in the United States, and this may not be adequate despite all efforts to increase the use of coal and nuclear energy. Thus, some imports of oil would probably be needed even though a net energy balance is achieved -- perhaps allowing the United States to trade coal for oil. This situation would probably continue until coal liquefaction on a large-scale is a reality, that is, well beyond 1985.

o A rapid achievement of zero imports would require a wartime, government-directed approach with serious economic and personal dislocations, as well as with substantial interim imports of oil, but for a more limited period. Higher energy prices would also result.

o Worldwide resources of oil and gas are limited. Long-range research on new energy sources for the longer term is essential and must receive strong support now. Important areas are breeders, fusion, solar energy, and systems for utilizing electric energy for transport (hydrogen, storage batteries, etc.). Some choices may have to be made between development work in support of the production programs and longer-range R&D because of the limited supply of scientists and engineers.

o More detailed studies need to be made with respect to a number of areas discussed in this study. These include the following:

- A more detailed examination of the supply and demand situation in the period between now and 1985, essentially on a year-by-year basis.
- Examination of energy supplies and demands, especially for oil, on a worldwide basis, to evaluate actual possibilities for import of oil into the Unites States in the 1985 time period, as well as possible prices for such imported oil.
- A more detailed examination of the methods of reducing demand by various economic and technical means.
- More detailed evaluations of the resource requirements and availabilities involved in large-scale energy programs, including scientific, engineering, and construction manpower; raw materials; equipment supply and manufacturing capabilities; water supplies; and local and general environmental effects and trade-offs.
- Examination in more detail of the development support required for the programs outlined.
- Development of a sound basis for government-industry joint efforts in such programs as coal liquefaction, tertiary oil recovery, or any areas judged to require significant government financial assistance.

o The energy program described herein is a major national endeavor involving both government and industry. To succeed, it must be conducted in an open manner in order to receive the necessary public understanding and support.

Beyond 1985: Achieving the complete range of programs described in this report by 1985 is not considered by the Task Force to be of high probability. Even if it is accomplished, the United States would be buying time. For beyond 1985 looms an ominous prospect of even greater demands for energy from ever-increasing and ever-rising expectations at home and abroad.

Unless innovative ways are developed for conserving and using energy and substantial new sources and new technologies are found for increasing energy supplies, the strategies presented by the Task Force would only postpone a grim future of energy scarcity.

Appendix A

NATIONAL ACADEMY OF ENGINEERING
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Appendix B

UNITS AND CONVERSION FACTORS

An effort has been made to make the units used throughout this report internally consistent and related as closely as possible to similar terms used in other reports. There are, however, difficulties in achieving such consistency since energy is treated in so many ways and with so many different units. For example, the following three classifications have been used in the references, as discussed below.

Energy. Absolute energy quantities are generally expressed in terms of British Thermal Units (Btu) per year. Many years ago, a unit called the Q was defined as 10^{18} Btu, and the practical unit is the milli-Q (mQ), or 10^{15} Btu.

In this report, the commonly used unit of energy is millions of barrels per day of crude oil or oil equivalent (MBPD). This is useful since many other reports use this same unit, which is the basic unit used in the oil industry. One barrel of oil is defined as having 5,800,000 Btu.

While this appears rather straightforward, it must be recognized that in the United States energy values are usually the higher or gross heating value of fuels, while in Europe such values are usually based on the lower or net heating values. The difference is on the order of 10 percent for gas and 5 percent for oil and coal.

Another complication is that some forms of energy are transformed into total energy at arbitrary conversion rates—for example, hydroelectric power. Although this energy in falling water is converted to electrical energy with an actual efficiency of 90 to 95 percent, it is sometimes presented as having been produced by fossil-fueled generating plants having a lower efficiency since it would replace that quantity of fossil fuels. In a few studies, the direct energy equivalent was used instead of this assumed required substitution.

Physical. Nominal physical quantities may be used. Where such units are used in this report, they are based on the following conversions:

- o 5,800,000 Btu per barrel of oil
- o 1,030 Btu per standard cubic foot (SCF) of natural gas

- 24,400,000 Btu per short ton of eastern coal (12,200 Btu per pound)
- 17,000,000 Btu per short ton of western coal (8,500 Btu per pound)

Actual physical quantities of material produced, shipped, or converted may differ appreciably from the nominal values specified above due to the variations in heat content of the various forms of even the same type of fuel.

For example, residual fuel oil used in power plants generally has a heating value of about 6.3 MBtu/barrel. Thus for a nominal 1 MBPD, the actual volume of residual fuel oil would be 920,000 BPD.

On the other hand, some western lignite coals have a heating value of perhaps 6,500 Btu/lb as shipped, and 1.0 BMPD of oil equivalent in such coal would be 163 MTPY of actual coal shipped instead of 125 MTPY of nominal western coal.

In the same way, the physical volume of low- and intermediate-Btu gas produced from coal may be several times the nominal amounts deduced from the MBPD oil equivalent, since these gases may have heating values of 150 to 500 Btu/SCF rather than the nominal value of 1,030 Btu/SCF that is representative of natural gas and high-Btu "pipeline quality" synthetic natural gas (SNG).

Units Used in this Report. As noted above, somewhat arbitrary conversion factors must be used in equating the energy input of electric generating plants to the total energy input based on the production of electricity. A nominal heat rate of 9,600 Btu per net kwh of electricity produced has been used in this report in converting nonfossil power generation energy output to equivalent oil-fired power generation energy input. This same nominal heat rate has been used for calculating the energy input to all forms of fossil-fired power plants.

There are a great variety of alternative terminologies and abbreviations which have grown up in the separate sectors of the energy industry. In an effort to simplify these to the least complicated terms for the nontechnical reader, we have adopted some terms which are not the normal ones used in the respective industry sector.

In this report the following terms are used:

ABBREVIATIONS USED

Term	Abbreviation	Equivalent
Kilowatt	Kwe	10^3 watts electrical
Megawatt	Mwe	10^6 watts electrical
Gigawatt	Gwe	10^9 watts electrical
Kilowatt-hour	Kwh	10^3 watthours electrical
Million BPD	MBPD	10^6 barrels per day oil
Million TPY	MTPY	10^6 tons per year solids
Billion CFD	BCFD	10^9 cubic feet per day
Trillion CFY	TCFY	10^{12} cubic feet per year

In summary, the following are the key conversion factors used in this report to obtain the oil equivalent expressed in million barrels per day (MBPD).

To Obtain	Divide	By
MBPD Oil Equivalent	Btu per year	2.12×10^{15}
	mQ's	2.12
	MTPY of Eastern Coal	86.8
	MTPY of Western Coal	125
	BCFD of Natural Gas	5.63
	TCFY of Natural Gas	2.06
	10^{18} Joules per year	2.23

Appendix C

This appendix contains a compilation of selected "demand or consumption" forecasts and selected "supply" forecasts for the years 1980 and 1985. In all "demand or consumption" cases, the quantities shown are in terms of 5.8-million-Btu barrels of oil. In all "supply" cases, the units shown are the energy equivalents of the units used by the forecaster.

Appendix C 1980 Supply–MBPD

Energy Source	1972, NPC Case I[10]	1972, NPC Case II[10]	1972, NPC Case III[10]	1972, NPC Case IV[10]	1973, JCAE[40]	1973, JCAE[41]	1973, IGT Pre-73 Scenario[42]	1973, IGT Post-73 Scenario[42]	1973, Shell Oil[38]	1972, Dept. of the Interior[1]	1968, Bureau of Mines[43]	1973, Stanford Research Institute[44]	1973, AGA[45]	1972, Bureau of Natural Gas[46]	1972, AEC[18]	1971, Denver Research Institute[47]	1974, Federal Energy Office (Policy)[48]	1974, Federal Energy Office–Base Case[49]	1974, Federal Energy Office–High Case[49]	Range	
																				High	Low
FOSSIL FUELS																					
Petroleum																					
Domestic	13.112	12.497	11.237	8.555	11.3	11.5	11.9	13.3	10.3	11.7	11.74						13.2	10.9	13.0	13.3	8.5
Imports					10.0	10.8	10.6	4.0	14.1		2.04									14.1	2.0
Shale syncrude	.139	.093	.093				.1	0.538		9.1							.5	Nil	.5	.5	0
Coal syncrude	.083							0.695	.2								.9			.9	0
Total petroleum	13.334	12.590	11.330	8.555	21.3	22.3	22.6	18.497	24.6	20.8	13.78						14.6	10.9	13.5	24.6	8.5
Coal	10.014	8.637	8.637	8.290	10.1	10.0	9.1	9.101	7.0	7.95	9.03						10.3	8.5	11.4	11.4	7.0
Gas																					
Domestic	12.634	11.829	9.939	8.458	10.0	8.5	10.0	12.471	8.95	11.32	11.60			9.8			12.5	9.5	11.5	12.6	8.5
Imports					1.9	1.8	2.1	0.858	1.05	1.98	.32			1.7						2.1	.3
Syngas	.339	.204	.204	.078	.4	.5	.1	0.896	1.30	.35				.5			.7		.3	1.3	0
Total gas	12.973	12.033	10.143	8.526	12.3	10.8	12.2	14.225	11.30	13.65	11.92		11.9	12.0		18.6	13.2	9.5	11.8	18.6	8.5
Total fossil fuels	36.321	33.260	30.110	25.371	43.7	43.1	43.9	41.823	42.90	42.40	34.73						38.1	28.9	36.7	57.4	25.4
OTHER																					
Nuclear	5.361	5.360	4.623	3.206	3.6	4.5	4.6	4.648	4.0	3.31	1.91				2.64		3.5	3.3	3.8	5.4	1.9
Hydro	1.530	1.530	1.530	1.503	1.8[a]	1.5[a]	1.7	1.712		1.97	1.409						1.4	1.4	1.4	1.9	1.4
Geothermal	.369	.189	.162	.090	0.2	.1											.6	.1	.7	.7	.1
Solar																			0	0	–
Total other	7.260	7.079	6.315	4.799	5.6	6.1	6.3	6.360	4.0	5.28	3.319						5.5	4.8	5.9	7.3	3.3
SUBTOTAL, DOMESTIC	43.582	40.341	36.426	30.209	37.4	36.6	37.5	43.325	31.75		35.697						43.6	33.7	42.6	43.6	42.6
SUBTOTAL, IMPORTS					11.9	12.6	12.7	4.858	15.15		2.360						-.7	12.6	-.7	15.2	-.7
GRAND TOTAL					49.3	49.2	50.2	48.183	46.90	47.68	38.052	42.2					42.9	46.3	41.9	50.2	38.1

[a] Hydropower converted to 10,250 Btu/kwh heat rate.

Appendix C 1985 Supply–MBPD

Energy Source	1972, NPC Case I[10]	1972, NPC Case II[10]	1972, NPC Case III[10]	1972, NPC Case IV[10]	1973, JCAE[41]	1973, IGT Pre-73 Scenario[42]	1973, IGT Post-73 Scenario[42]	1973, Shell Oil[38]	1972, Dept. of the Interior[1]	1973, Stanford Research Institute[44]	1973, AGA[45]	1972, Bureau of Natural Gas[46]	1972, AEC[18]	1971, Denver Research Institute[47]	1974, Federal Energy Office–Base Case[49]	1974, Federal Energy Office–High Case[49]	Range		This Study
																	High	Low	
FOSSIL FUELS																			
Petroleum																			
Domestic	14.969	13.452	11.500	10.121	11.0	11.7	14.5	10.2	11.7						10.4	16.2	16.2	10.1	12.5
Imports					14.6	13.7	2.6	17.8	13.3								17.8	2.6	-
Shale syncrude	.698	.372	.372	0.093	0.1	.3	1.027								.3	1.4	1.4	0	.5
Coal syncrude	.703	.083	.083			.2	1.292	.6									1.3	0	.6
Total petroleum	16.370	13.907	11.955	10.214	25.7	25.9	19.419	28.6	25.0	30.89					10.7	17.6	30.9	10.2	13.6
Coal	12.801	10.103	10.103	9.589	11.1	10.5	10.511	8.5	10.58	9.32					11.2	18.0	18.0	8.5	10.0
Gas																			
Domestic	14.929	12.907	9.943	7.309	7.1	9.5	14.205	7.40	11.09			8.9			8.8	11.7	14.9	7.1	14.5
Imports					3.0	2.9	1.058	1.95	2.90			2.4			–	–	3.0	1.1	–
Syngas	1.705	.960	.960	0.233	.7	.5	1.744	1.75	.99			1.3					1.8	0	1.1
Total gas	16.634	13.867	10.903	7.542	10.8	12.9	17.007	11.10	14.98	12.52	14.5	12.6		21.1	8.8	11.7	21.1	7.5	15.6
Total fossil fuels	45.805	37.877	32.961	27.346	47.6	49.3	46.937	48.20	50.56	52.73					30.7	47.3	52.7	27.3	39.2
OTHER																			
Nuclear	14.081	11.927	9.55	7.617	9.4	10.3	10.274	8.5	5.79	7.20			5.408		5.6	8.6	14.1	5.4	8.3
Hydro	1.563	1.568	1.568	1.568	1.5[a]	2.0	1.957		2.13	1.40					1.4	1.6	2.0	1.4	1.5
Geothermal	.659	.312	.243	0.121	.2										.3	1.4	1.4	.1	.2
Solar															–	1.9	1.9	0	–
Total other	16.308	13.807	11.361	9.306	11.1	12.3	12.231	8.5	7.92	8.73					7.3	13.5	16.3	7.3	10.0
SUBTOTAL, DOMESTIC	62.114	51.684	44.323	36.652	41.1	45.0	55.501	36.95							38.0	60.8	62.1	36.7	49.2
SUBTOTAL, IMPORTS	5.80				17.6	16.6	3.658								16.7	-9.9	16.7	-9.9	
GRAND TOTAL					58.7	61.6	59.159	56.70	58.48	61.46					54.7	50.9	61.5	50.9	

[a] Hydropower converted to 10,250 Btu/kwh heat rate.

Appendix C 1985 Demand or Consumption–MBPD[a]

Energy Source	1972, NPC – Low Level[10]	1972, NPC – Intermediate Level[10]	1972, NPC – High Level[10]	1972, Associated Universities, Inc.[39]	1972, Department of the Interior[1]	1972, Stanford Research Institute[36]	1973, Council on Environmental Quality[37]	1972, Shell Oil[38]	1973, Energy Policy Office (Dixy Lee Ray Report)[3]	Range High	Range Low
FOSSIL FUELS											
Petroleum				24.19	25.0	32.0	25.49			32.0	24.2
Coal				10.20	10.63	7.2	10.15			10.6	7.2
Gas				12.55	14.05	14.0	13.61			14.1	12.6
Total fossil fuels				46.94	49.68	53.2	49.25			53.2	46.9
OTHER											
Nuclear, Hydro, Geothermal				8.18	7.5[illegible]	14.3	9.16			14.3	8.0
GRAND TOTAL	53.2	59.0	61.3	55.12	57.73	67.5	58.41	62.0	57.0	67.5	53.2
Demand (D) or Consumption (C) Type Projection	D	D	D	?	C	D?	C?	C	C		

[a] The difference between demand and consumption is U.S. exports, which in 1973 amounted to approximately 1 MBPD. Demand also reflects changes in U.S. energy inventory, which are usually small.

Appendix C 1980 Demand or Consumption–MBPD[a]

Energy Source	1972, NPC – Low Level[10]	1972, NPC – Intermediate Level[10]	1972, NPC – High Level[10]	1973, Bechtel[35]	1972, Department of the Interior[1]	1972, Stanford Research Institute[36]	1973, Council on Environmental Quality[37]	1972, Shell Oil[38]	1973, Energy Policy Office (Dixy Lee Ray Report)[3]	Range High	Range Low
FOSSIL FUELS											
Petroleum				24.0	20.9	27.0	20.31			27.0	20.3
Coal				8.5	7.99	7.0	7.09			8.5	7.0
Gas				9.7	13.36	13.0	13.46			13.5	9.7
Total fossil fuels				42.2	42.25	47.0	40.86			47.0	40.9
OTHER											
Nuclear, Hydro, Geothermal				4.8	5.31	6.45	4.96			6.5	4.8
GRAND TOTAL	45.2	48.4	49.7	47.0	47.53	53.45	45.82	49.0	47.0	53.5	45.2
Demand (D) or Consumption (C) Type Projection	D	D	D	D	C	D?	C?	C	C		

[a] The difference between demand and consumption is U.S. exports, which in 1973 amounted to approximately 1 MBPD. Demand also reflects changes in U.S. energy inventory, which are usually small.

Appendix D

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